Final Report

Independent Peer Review of the U.S. Department of Energy Sandia National Laboratories' Mixed Waste Landfill

August 31, 2001

Performed by WERC:
A Consortium for Environmental Education and Technology Development

NOTICE

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Acknowledgements

WERC wishes to thank the following for their contributions: panel members Catherine Aimone-Martin, Michael Campana, Antonio Lara, Eric Nuttall, and Mary Walker; panel facilitators Ron Bhada and Tim Carlson; WERC staff Abbas Ghassemi, Jim Loya, Carolyn Perez, and Deb Thrall; presenters of information on the Sandia National Laboratories Mixed Waste Landfill: John Gould with U.S. Department of Energy; Dick Fate, Tim Goering, and Jerry Peace of Sandia National Laboratories; Will Moats of New Mexico Environment Department, and Douglas Earp from City of Albuquerque. A special thanks to Bruce Baker with Technadyne (Albuquerque) who designed the fate and transport model used in this report.

Agreement of Report Contents

The panel members who performed the peer review of the U.S. Department of Energy, Sandia National Laboratories, Mixed Waste Landfill have read the entirety of this peer review final report dated August 31, 2001, and concur with the contents herein.

Catherine Aimone-Martin — August 31, 2001
Catherine Aimone-Martin — Date

Michael C. Campana — August 31, 2001
Michael Campana — Date

Mary Walker — Aug 31, 2001
Mary Walker — Date

Antonio Lara — 31 Aug 2001
Antonio Lara — Date

H. E. Nuttall — Aug 31, 2001
Eric Nuttall — Date

Final Report Errata

p.4 – P 2 – line 4
replace “ccover” with “cover”
p.6 – P 4 – line 2
replace “curie” with “Curie”
p.7 – P 2 – line 3
replace “clothe” with “cloth”
p.19 – P 1 – line 2
replace “an open public meetings” with “open public meetings”
p. 19 – P 1 – line 21
replace “responses” with “responds”
p.20 – P 1 – line 3
replace “trough” with “through”
p. 20 – P 2 – line 1
replace “evaluation” with “evaluate”
p. 24 – P 5 – line 7
replace “pits were” with “pits, were”
p. 42 – P 5 – line 5
replace “none” with “non”
p. 44 – P 3 – line 1
replace “cool” with “coolant”
p. 45 – P 3 – line 4
replace “and an expert” with “and consultation with an expert”
p. 51 – P 5 – line 8
replace “And human” with “Human”
p. 55 – P 4 – line 1
replace “Baskaran” with “Baskaran’s”
p. 56 – P 1 – line 12
replace “interpretation, cannot” with “interpretation cannot”
p. 68 – P 1 – line 20
replace “and recently” with “and was recently”
p. 69 – P1 – line 5
replace “Dr Lara” with “Dr. Lara”
p. 69 – P 2 – line 12
replace “years both” with “years for both”
p. 69 - P 2 – line 13
replace “manage” with “management”
p. 70 – P 1 – line 7
replace “Dr Bhada” with “Dr. Bhada”
p 71 – P 2 – line 4
replace “Professor” with “Professor of”

Executive Summary

In January 2001, WERC (a Consortium for Environmental Education & Technology Development) was requested by the U.S. Congress to perform an independent peer review of the performance of the Mixed Waste Landfill (MWL) at the U.S. Department of Energy's (DOE) Sandia National Laboratories in Albuquerque, New Mexico.

DOE's preferred solution is to not excavate and treat the buried waste because of the significant concern for worker safety, but rather to place a 3-foot-thick vegetative cover on top of the landfill to improve the MWL's long-term performance. The performance characteristics of the cover are predicted by Sandia to achieve the regulatory goals of providing long-term protection of human health and the environment. Although not stated in any of the references, the preferred approach by DOE Albuquerque and Sandia National Laboratories (as expressed at the peer review session of March 22-23, 2001) also includes the reopening of the decision process in approximately 30 to 40 years to identify if new technologies are available to provide a more permanent solution. At that time, the risk to workers would be reduced because of the natural decay associated with some of the radionuclides.

The purpose of the peer review was to assess the validity of the assumptions that were used by DOE to evaluate historic performance of the MWL and its safety. An engineering evaluation of the cap design itself was not a part of this peer review. Additionally, the peer review was not to assess the appropriateness of DOE's historic or existing waste disposal practices, nor future missions or uses at Sandia National Laboratories. The review conducted was a high-level analysis, focused on determining the reasonableness of conclusions reached by DOE. The intent of the review was not to reproduce the calculations and results of the reports used to evaluate the MWL.

The peer review of Sandia's MWL was conducted at two separate public meetings in Albuquerque, New Mexico. Prior to these peer panel meetings, a separate public meeting was held at the University of New Mexico in Albuquerque to discuss the process, the role of WERC, and to gather public input. During the two actual peer review meetings, full and frank discussions occurred between the peer reviewers and the original performers of the work. The initial peer panel meeting (March 22 and 23, 2001) reviewed information on the site, historic waste inventory, soil and hydrologic information, characterization data, and critiques of DOE's work. A tour of the site was also made during this meeting. At the second peer panel meeting (May 11, 2001) the peer panel presented their initial findings and conclusions, and directed specific questions to DOE and Sandia National Laboratories representatives. The public meetings were advertised in the local Albuquerque newspapers.

A Draft MWL Peer Review report was made available to the public and DOE/Sandia in hard copy and through the Internet at www.werc.net on July 9, 2001. A public meeting to receive comments on this report was held on August 16, 2001. Comments received

were used to help the panel complete the final report. An addendum to this document will be made available by September 30, 2001 that responses to each comment received.

General Conclusions

1. In its review of MWL information and in its deliberations during March and May 2001 the peer panel identified that the information presented was consistently of high quality and the general approach taken by Sandia National Laboratories to evaluate the performance of the MWL is valid with conclusions drawn being reasonable.

2. Although there appears to be anecdotal information that implies that excavation of the MWL at this time would be too dangerous for worker safety, there is no documentation on actual risks, costs, or impacts to support this assumption. Additionally, there is no documentation as to when in the future such excavation might be appropriate.

3. The data pertaining to fate and transport of tritium from the MWL presented and reviewed in this report (specifically, the spatial and temporal distribution of sampled tritium activities), appear to be consistent with those expected given the inventory, regional meteorology, subsurface soil conditions, and hydrologic parameters.

4. Future concentrations of tritium are not expected to increase but rather are expected to decrease over the next 10 years based on the natural decay of the tritium radionuclide.

5. The MWL, to the knowledge of the reviewers, neither resulted in human exposure to contaminants nor resulted in any significant environmental damage to date. Continuation of monitoring at the site will be essential to determine if there is a potential for change in this status.

6. The hazardous/radioactive waste should ultimately be excavated and stored in a licensed repository if human exposure and/or significant environmental damage become imminent. The panel recommends that retrieval and disposal of the contaminants must be evaluated as part of a comprehensive alternatives evaluation report (please see Recommendation A).

7. The human health risk and the ecological risk screening assessment for the MWL is adequate and it would appear that the risk posed to human health and the environment from radiological and non-radiological contaminants of concern (COCs) is below that requiring action. This conclusion is based on the review of the existing risk assessment reports and assumes that existing conditions remain. It should be noted that the human health and ecological risk assessments are strictly based on the levels of contaminants that have been detected in soil and groundwater sampling. The assessments did not consider risks posed by other chemicals that are present in the MWL, based on the inventory, that have not been released into the environment.

8. A key issue that arose in the review of MWL reports, sampling data, and outside reviews was an argument that the U-238/U-235 activity ratios were less than 21.76 in ground water samples and hence suggested non-natural or anthropogenic (man caused) sources of uranium existed beyond the MWL. Evaluation of laboratory data indicates that past analytical measurements were highly variable, above and below the assumed natural value, and the precision was poor. A recent round of analytical testing provided a method of measuring isotopic activity ratios using mass spectrometry and the precision was very tight. The method strongly suggests that the uranium isotopic activity ratios are those of the natural abundance of the element and thus one can conclude that the MWL has not leached uranium into the groundwater.

Recommendations

A. Sandia National Laboratories should proceed with a comprehensive report that evaluates the options of excavating the MWL in the near future, placing a cover on the MWL with retrieval at some future time, a permanent cover with no retrieval, maintaining current conditions, and possibly other alternatives. This study should clearly articulate the risks, costs, and impacts associated with the different alternatives and the different points in time that actions may take place.

B. Since tritium is the one contaminant detected in soil sampling that clearly originated from the landfill, some additional explanation of the assumptions used in the risk assessment is needed for clarity, such as: for an industrial worker or for a resident how much soil is estimated to be ingested? How much inhalation occurs? It would also be useful to include a table that lists exposure levels (i.e. soil ingestion, inhalation, dermal exposure, and plant uptake).

C. To provide adequate communication to the public, Sandia National Laboratories should provide an explanatory executive summary for the human health risk assessment and the environmental risk assessment documents. This information should describe the basic risk assessment processes that were used, the identified contaminants of concern, the uncertainties associated with them, and the basic conclusions reached from these processes. This information may already exist in the public information efforts previously conducted by Sandia, however, it is lacking from the risk assessment documents made available to the public.

D. Although a recent round of analytical testing using mass spectrometry strongly suggests that the uranium isotopic activity ratios are those of the natural abundance of the element, a different laboratory should confirm this finding using similar analytical methods on a future round of groundwater sampling/testing.

E. It is recommended that Sandia National Laboratories compile all of the relevant information related to the MWL in one document series and make it accessible to the public. Much of this information is currently available in two public reading rooms in Albuquerque that are maintained by Sandia.

1.0 Introduction and Purpose

In January 2001, WERC (a Consortium for Environmental Education & Technology Development) was requested by the U.S. Congress to perform an independent peer review of the performance of the Mixed Waste Landfill at the U.S. Department of Energy's (DOE) Sandia National Laboratories. WERC's consortium members include New Mexico State University, University of New Mexico, New Mexico Institute of Mining and Technology, Diné College, Los Alamos National Laboratory, and Sandia National Laboratories.

DOE's preferred solution is to not excavate and treat the buried waste because of the significant concern for worker safety, but rather to place a 3-foot-thick vegetative cover with up to 40 inches of sub-grade for purposes of leveling the site and improving the cover's long-term performance. The addition of the ccover is to provide an extra level of protection and was recommended by the New Mexico Environment Department. The performance characteristics of the cover are predicted by Sandia to achieve the Resource Conservation and Recovery Act (RCRA) goals of providing long-term protection of human health and the environment. Although not stated in any of the references, the preferred approach by DOE Albuquerque and Sandia National Laboratories (as expressed at the peer review session of March 22-23, 2001) is to reopen the decision process in approximately 30 to 40 years to identify if new technologies are available to provide a more permanent solution. At that time, the risk to workers would be reduced because of the natural decay associated with some of the radionuclides.

The purpose of this peer review is to assess the historic performance of the Mixed Waste Landfill (MWL) and its safety. An engineering evaluation of the cover design itself is not a part of this peer review.

Peer panel members and their affiliation are:

Dr. Catherine Aimone-Martin	New Mexico Institute of Mining and Technology
Dr. Michael Campana	University of New Mexico
Dr. Antonio Lara	New Mexico State University
Dr. Eric Nuttall	University of New Mexico
Dr. Mary Walker	University of New Mexico

Panel facilitators who conducted the public sessions and their affiliations are:

Dr. Ron Bhada	New Mexico State University and WERC (retired)
Tim Carlson	Sensible Environmental Solutions

WERC staff who provided logistical support are: Dr. Abbas Ghassemi, Jim Loya, Carolyn Perez, and Dr. Deb Thrall. Biographic sketches of the panel members and the panel facilitators used to generate the peer review report are included in Appendix A.

2.0 Background on the Mixed Waste Landfill

2.1 Landfill Setting

Background on the MWL is summarized from documents provided by DOE and Sandia and is intended to provide the reader with a general understanding of the physical setting and history of the landfill (see Appendix D, documents 2, 3, 4, 5, and 6). The MWL is located five miles southeast of the Albuquerque International Airport on Sandia National Laboratories property known as Technical Area 3 (see Figure 1). The site is situated within a large north-south trending basin in the Rio Grande trough. The basin is a compound graben that has been filled, up to a depth of 12,000 feet, from the erosion of the surrounding highlands. Situated on coalescing alluvial fans emanating from the Manzanita Mountains to the east, the site has underlying deposits that are characterized by great internal variability. The alluvium, which makes up the vadose zone, is a well-graded, fine sand with occasional layers of gravel, coarse sands, or finer material.

An extensive vadose zone underlies the landfill with the water table being approximately 460 feet below the ground surface. This unconfined aquifer in the unconsolidated Santa Fe Group sediments is part of the primary drinking water supply for the City of Albuquerque and surrounding communities. Recharge resulting from direct infiltration of precipitation is insignificant due to the high evapotranspiration, low precipitation, and extensive vadose zone. Groundwater gradients in the area average 10 feet per mile.

At and near the MWL there are no natural surface run-off features. Surface runoff is regionally controlled and flows generally to the west. There are no man-made surface runoff controls. All surface runoff from the landfill is to dirt roads that surround the site. Precipitation averages about 8.5 inches per year of which snowfall averages about 11 inches per year. Summer precipitation, particularly in July and August, is usually in the form of heavy thunderstorms that typically last less than one hour at any given location. The average annual potential evapotranspiration is estimated at 75.4 inches. Winds speeds seldom exceed 32 miles per hour and are generally less than 8 miles per hour.

2.2 MWL Inventory of Disposed Materials

The MWL occupies approximately 2.6 acres and was operated between March 1959 and December 1988. During this period of time, it was the primary disposal site for Sandia's nuclear weapons research and development activities. The MWL was originally opened as the "Area 3 Low-Level Radioactive Dump" when the radioactive dump in the Technical Area 2, which is closer to the airport, was closed in March 1959. Approximately 100,000 cubic feet of low-level radioactive waste and minor amounts of mixed waste containing approximately 6,300 Curies of activity (at the time of disposal)

were disposed at the MWL. Mixed waste is defined as waste that contains both hazardous waste, as defined by the U.S. Environmental Protection Agency (EPA), and radioactive waste. Because hazardous wastes were disposed at the MWL, the State of New Mexico is authorized by the EPA to implement the hazardous waste management provisions of RCRA for treatment, storage, and disposal facilities within the state. Under RCRA, the New Mexico Environment Department regulates the MWL as a Solid Waste Management Unit (SWMU) as a corrective action. DOE orders also provide requirements for landfill closure and cover design, and establish long-term performance requirements for the closed facility.

The MWL consists of two distinct disposal areas: the classified area, occupying 0.6 acres, and the unclassified area, occupying 2.0 acres (Figures 2 and 3). Classified wastes are materials that are considered to have national security value and are not subject to public disclosure and are disposed in Pits 1 through 37, Pits SP-1 through SP-5, and Pits U-1 through U-3. They may include documents, materials, or physical configurations. Wastes in the classified area were disposed in a series of vertical, cylindrical pits. Historic records indicate that early pits were 3 to 5 feet in diameter and 15 feet deep. Later pits were 10 feet in diameter and 25 feet deep. A typical disposal of classified materials is represented in Figure 4. Once pits were filled with waste, they were backfilled with soil then capped with concrete. Wastes in the unclassified area (Trenches A through G) were disposed in a series of parallel, north-south excavated trenches. Records indicate that the trenches were 15 to 25 feet wide, 150 feet to 180 feet long, and 15 to 20 feet deep. Trenches were reportedly backfilled with soil on a quarterly basis and, once filled with waste, capped with originally excavated soils that had been stockpiled locally. Figures 5 through 8 show how wastes were typically disposed in the unclassified area.

Wastes disposed in the classified area pits included depleted, natural, and enriched uranium; thorium; barium; enriched lithium; liquid scintillation vials and beakers; neutron generator tubes and targets; plutonium contaminated wastes; and plutonium contaminated weapons test debris from DOE's Nevada test site. Figure 9 presents the tritium disposed in the classified area between 1959 and 1983. Between 1959 and 1962, small quantities of radioactively contaminated inorganic acids and organic solvents were disposed in Pit SP-1 located in the southeast corner of the classified area. Wastes disposed in the unclassified area trenches included construction and demolition materials, contaminated equipment and soils, lead shielding, shipping casks, cardboard, dry solids, and various crates, drums, and boxes. Wastes were disposed in this area at random with no regard to waste source or type.

In 1967, trench D in the unclassified area was used for disposal of an estimated 204,000 gallons of reactor coolant water. Sandia's records estimate that 1 curie of total radioactivity (primarily from tritium, and possibly from Na-24 and Mn-56) was discharged into the trench over a period of one month. Disposal began at 11:30 a.m. May 11, 1967, and continued more or less continuously until 12:45 p.m. on June 22, 1967.

Containment and disposal of waste commonly occurred in tied, double polyethylene bags, sealed A/N cans (military ordnance metal containers of various sizes), fiberboard drums, wooden crates, cardboard boxes, 55-gallon drums, and 55-gallon polyethylene drums. Larger items such as glove boxes and spent fuel shipping casks were disposed in bulk without any additional containment. Except as noted above, disposal of free liquids was not allowed at the MWL. Liquids such as acids, bases, and solvents were solidified with commercially available agents such as Aquaset®, Safe-T-Set®, Petroset®, vermiculite, marble chips, or yellow powder before containerization and disposal.

Most pits and trenches also contain routine operational and miscellaneous decontamination waste such as: gloves, paper, mop heads, brushes, rags, tape, wire, metal and PVC tubing, cables, towels, quartz clothe, swipes, disposable lab coats, shoe covers, overalls, HEPA filters, prefilters, tygon tubing, watch glasses, polyethylene bottles, beakers, balances, pH meters, screws, bolts, saw blades, Kleenex®, petri dishes, scouring pads, metal scrap and shavings, foam, plastic, glass, rubber scrap, electrical connectors, ground cloth, wooden shipping crates and pallets, wooden and Lucite® dosimeter holders, and expended or obsolete experimental equipment.

The MWL waste inventory, by pit and trench, is provided in Appendix B.

To investigate the potential for contamination in the soil and the vadose zone, 13 angled boreholes and 2 vertical boreholes were drilled around the perimeter of the landfill to a depth of approximately 120 feet (Figure 10). An additional 18 bore-holes were drilled around the perimeter of the MWL during the Phase 1 RCRA Facility Investigation, conducted in 1989 and 1990. To monitor for groundwater contamination, 7 monitoring wells were drilled around the perimeter of the landfill, one of which was in a generally upgradient location. Additionally, one monitoring well was placed inside the unclassified area of the landfill. Monitoring well locations are presented in Figure 11 and penetrate the underlying aquifer a minimum of 110 feet to a maximum of 160 feet.

Figure 1: Location of Kirtland Air Force Base and Sandia National Laboratories

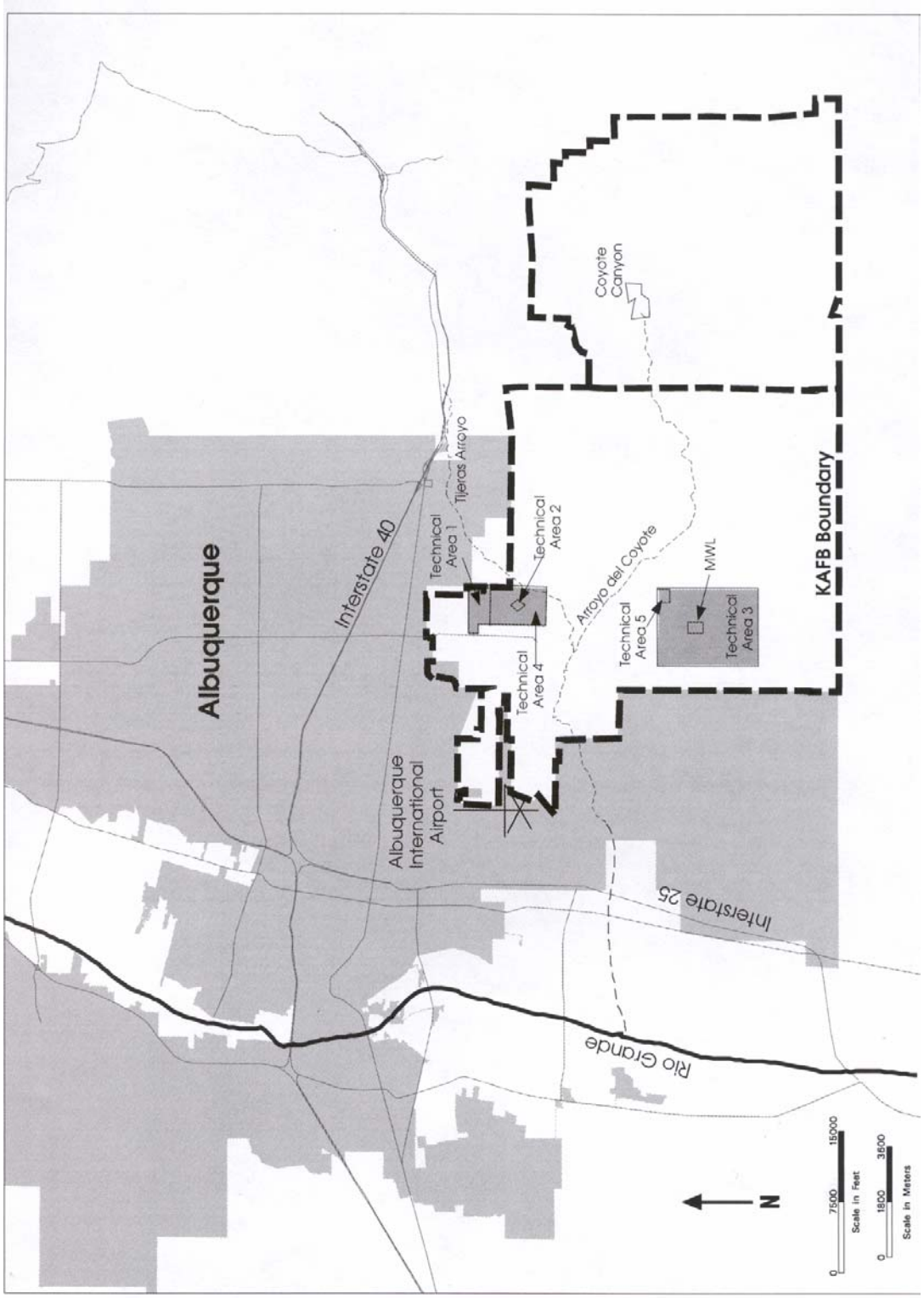


Figure 2: Mixed Waste Landfill Trenches and Pits

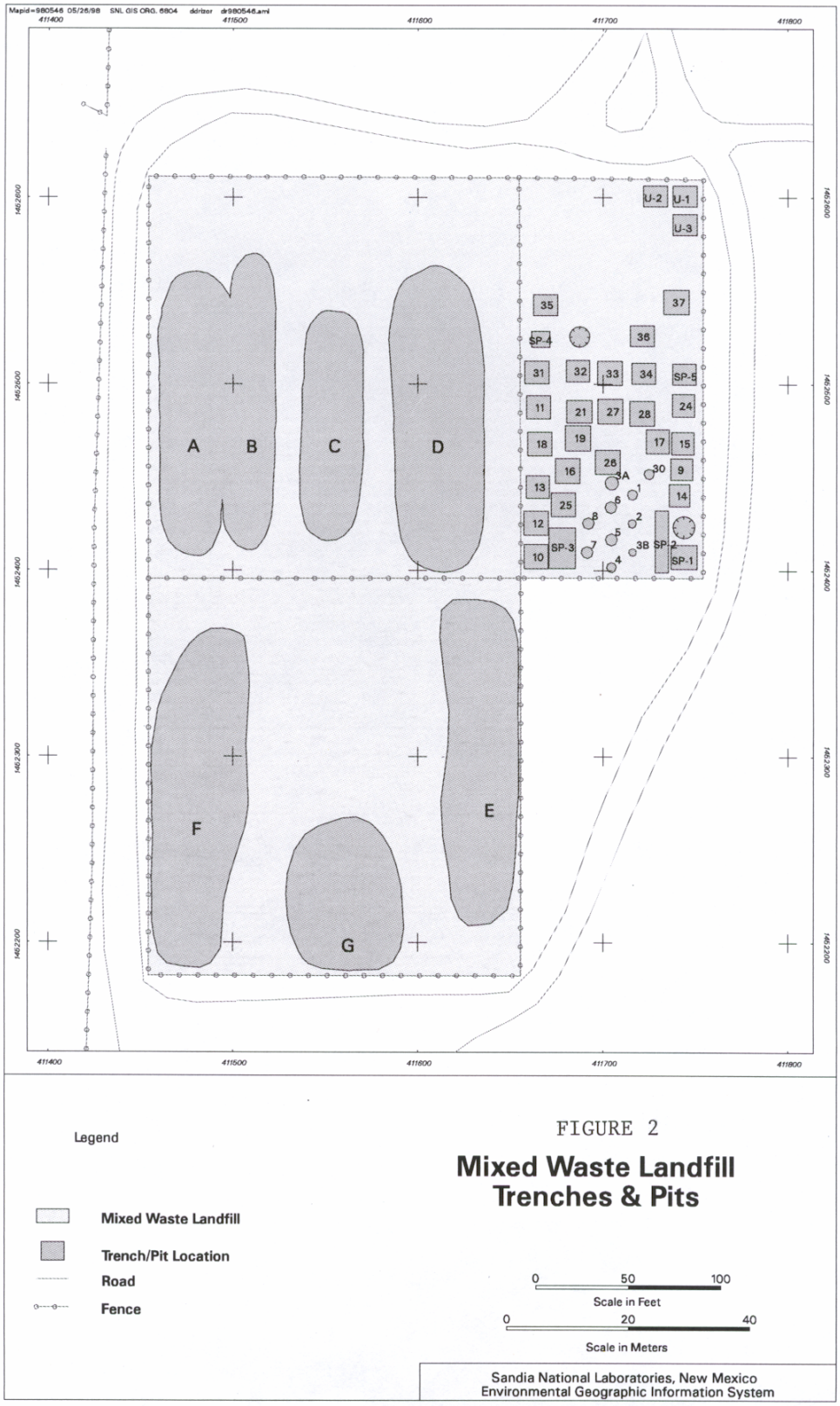


Figure 3: Oblique Areal View of Mixed Waste Landfill, looking Southwest, circa 1987

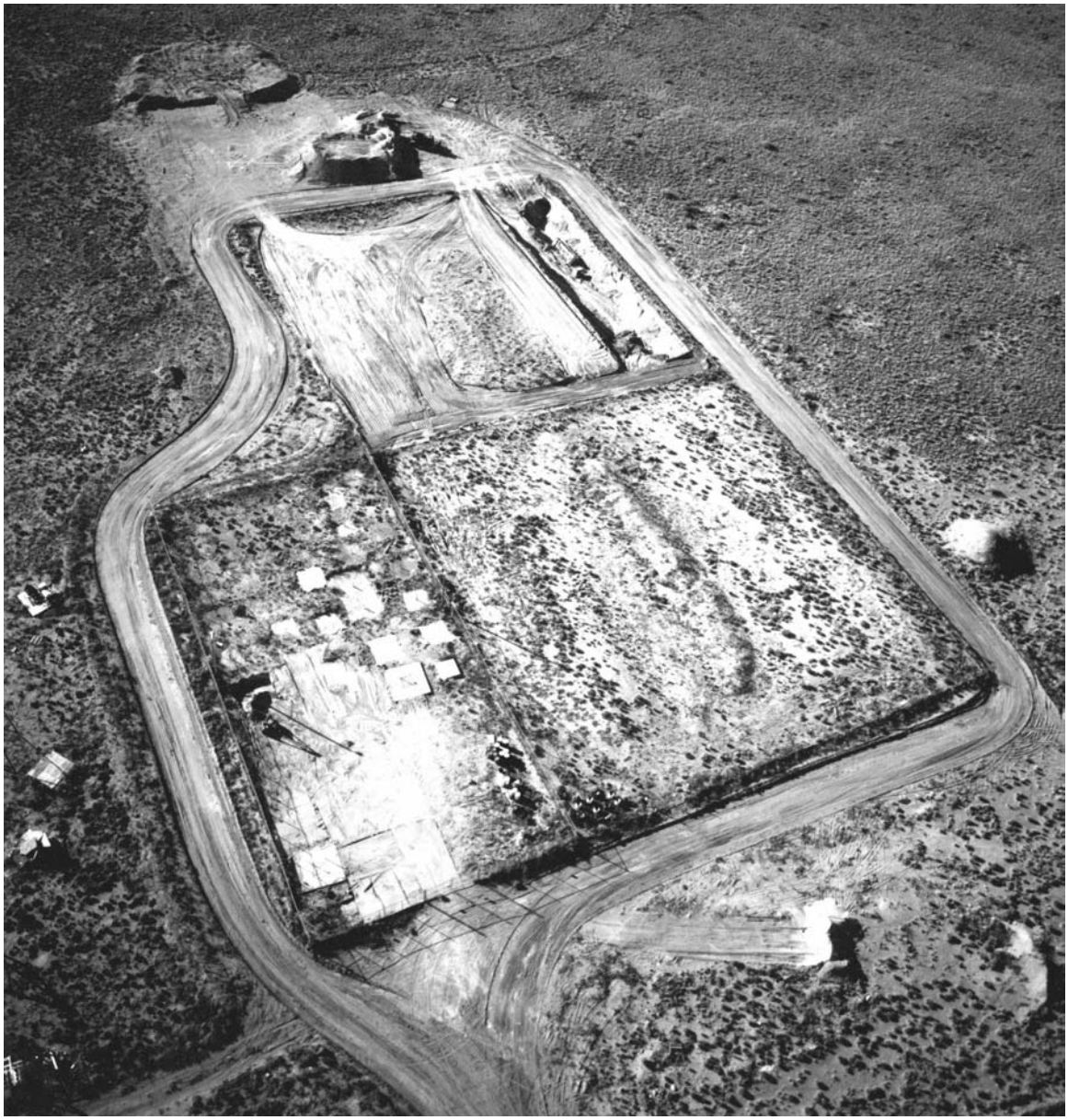


Figure 4: Mixed Waste Landfill, “Classified Waste” Disposal, circa 1974

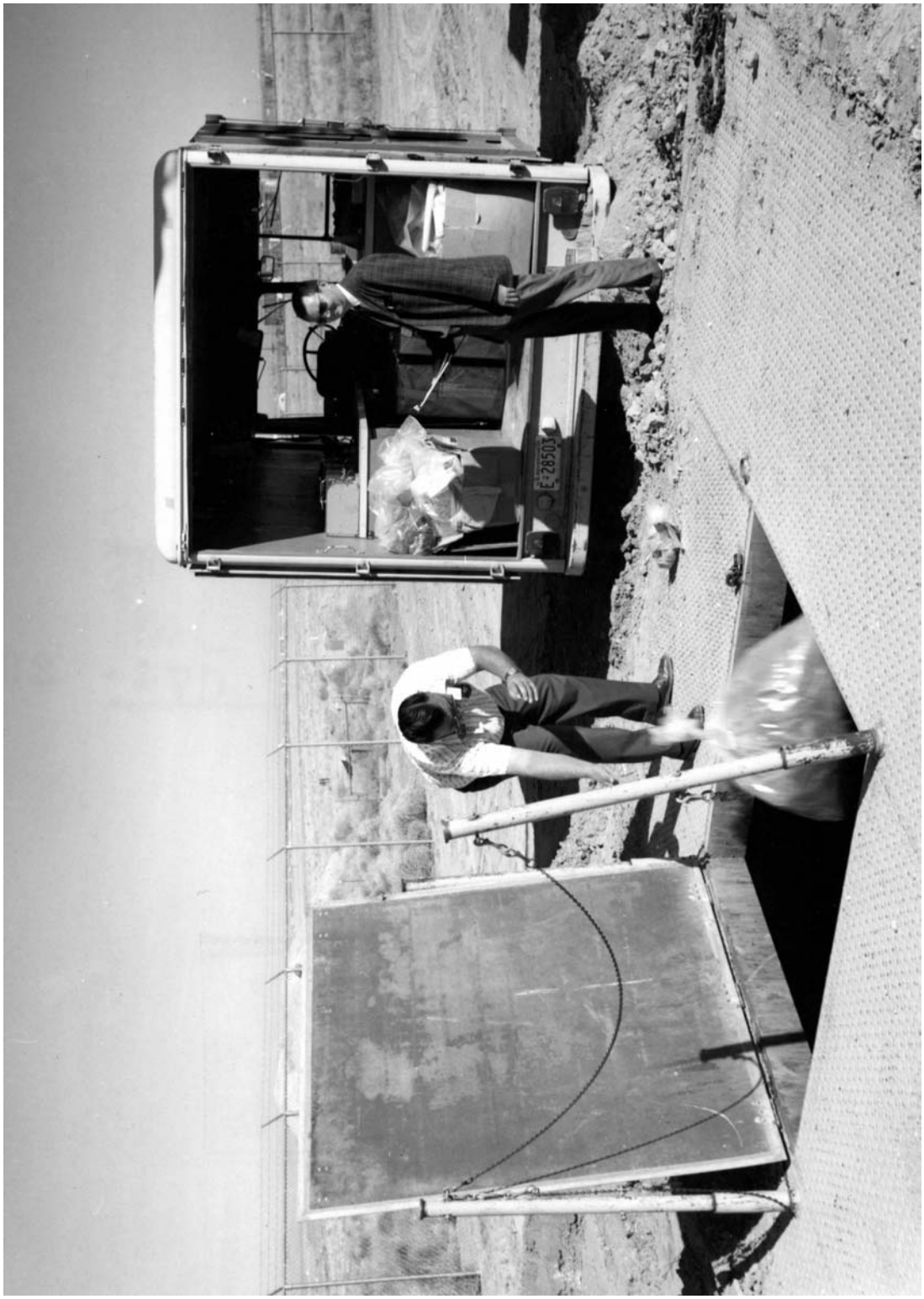


Figure 5: Lovelace Waste in Trench E, looking South, May 1980

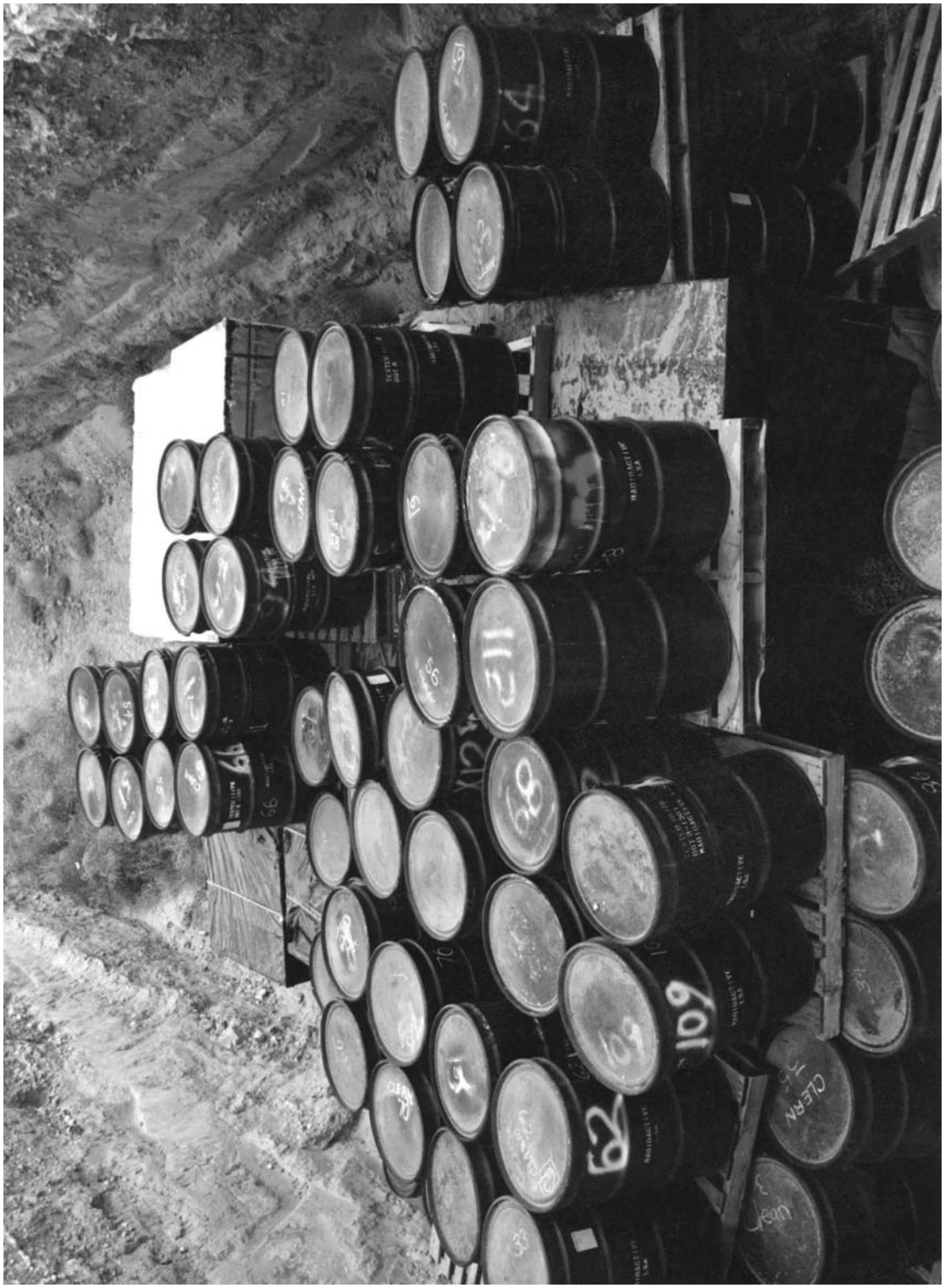


Figure 6: "Unclassified Waste" Disposal in Trench B, looking South, circa 1974

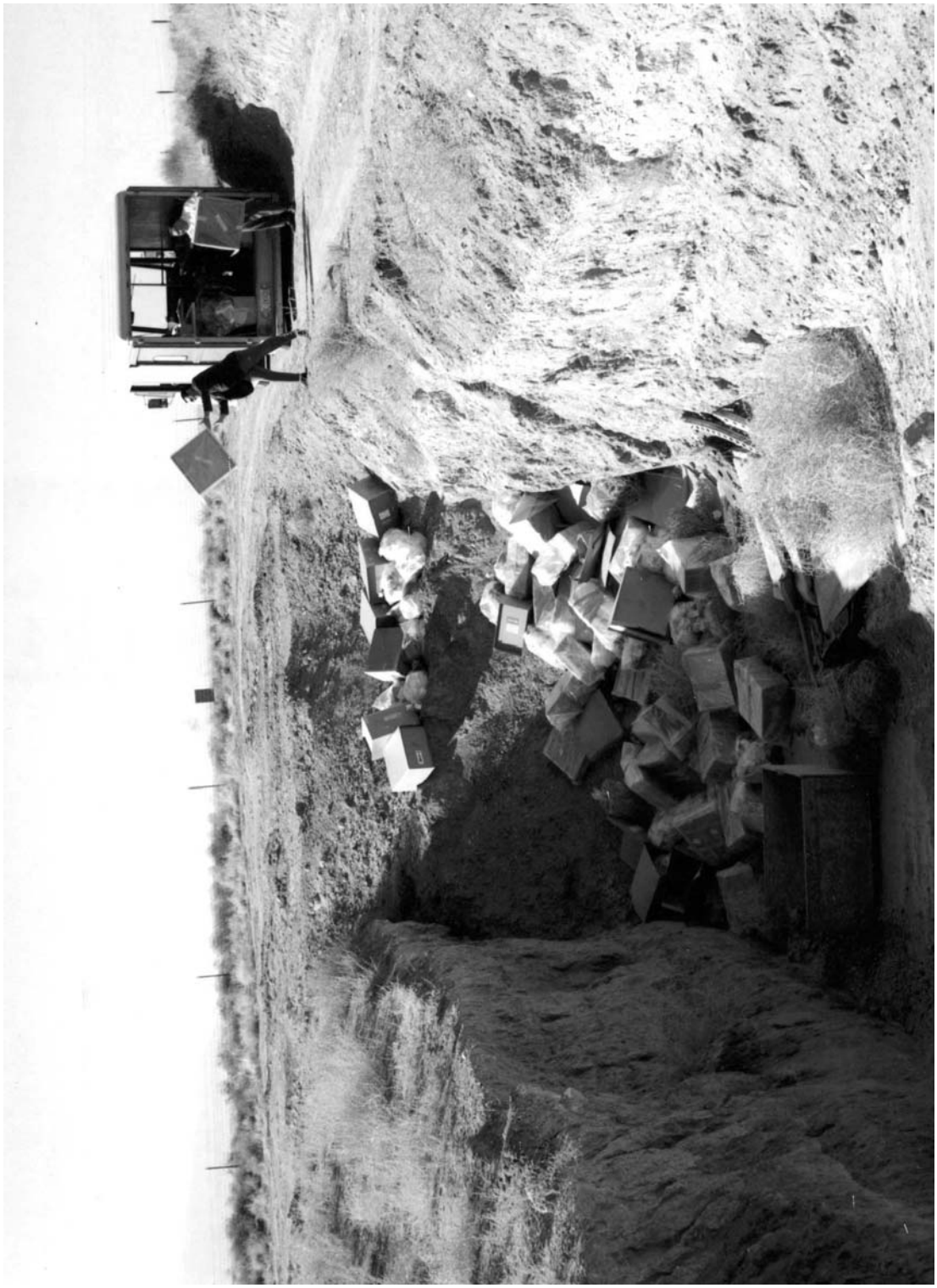


Figure 7: Trench F looking South, circa 1987

Figure 8: Trench D looking South, circa 1966

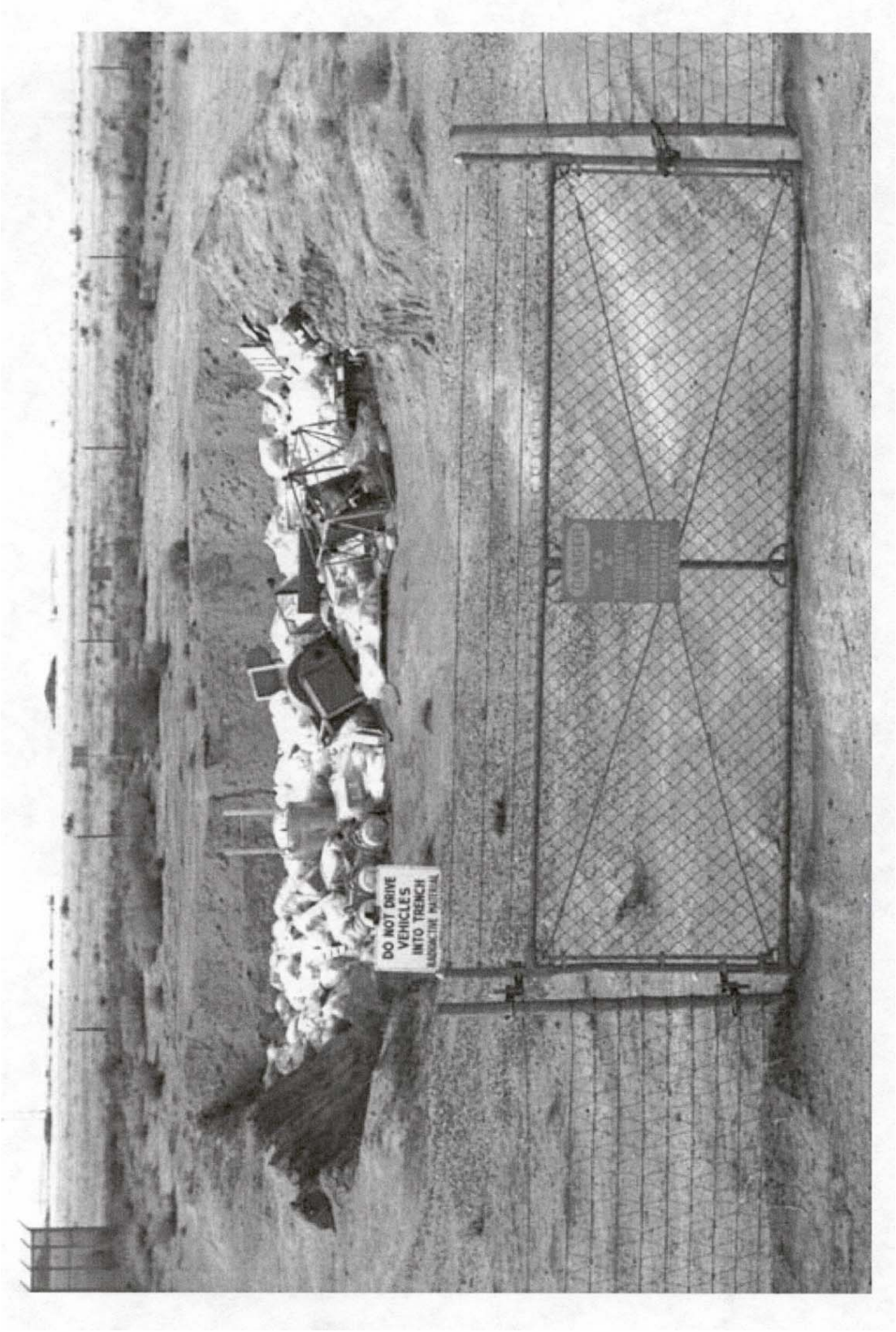


Figure 9: Classified Area Tritium Disposal, 1959-1983

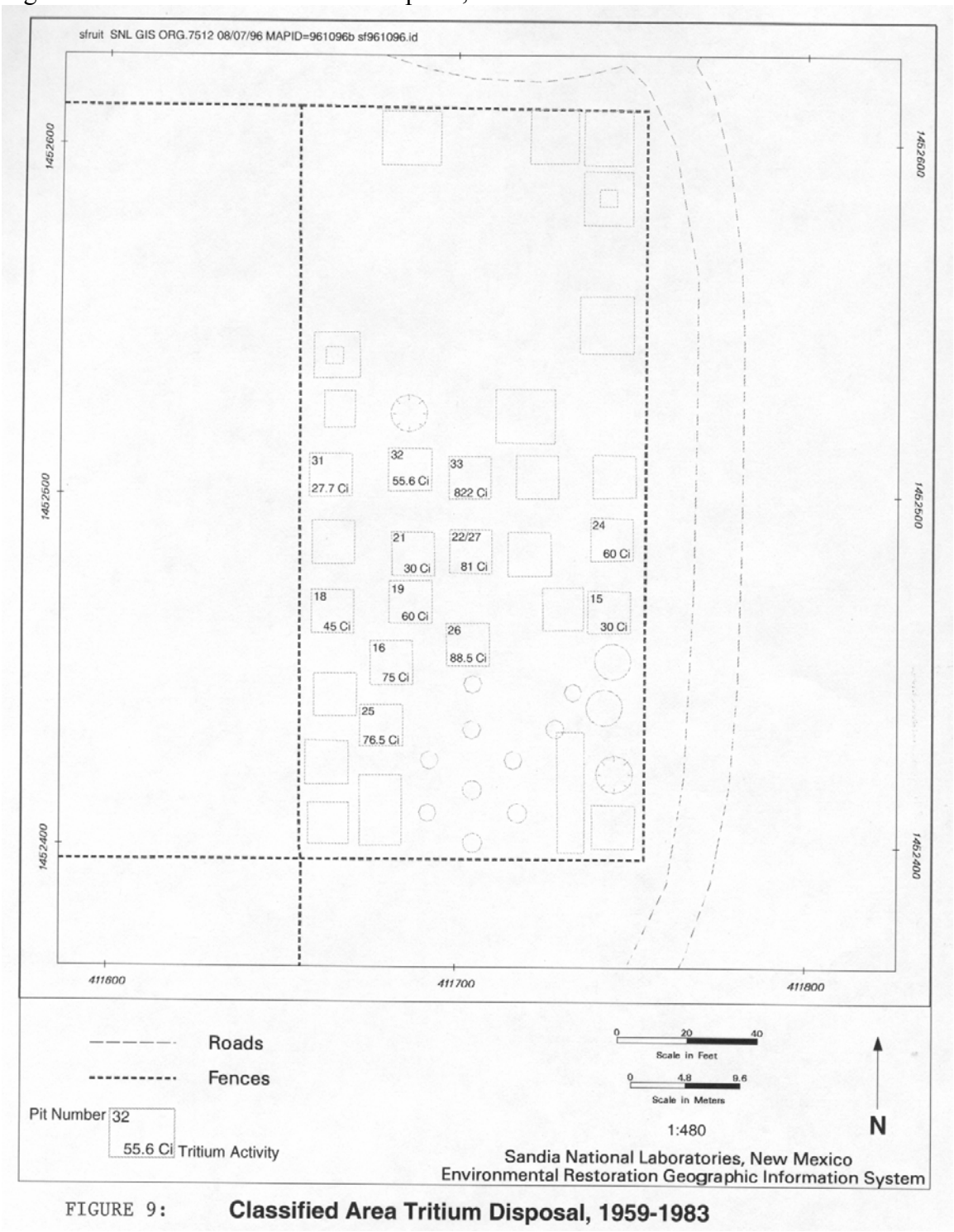


FIGURE 9: **Classified Area Tritium Disposal, 1959-1983**

Figure 10: Phase 2 RFI Soil Boring Locations

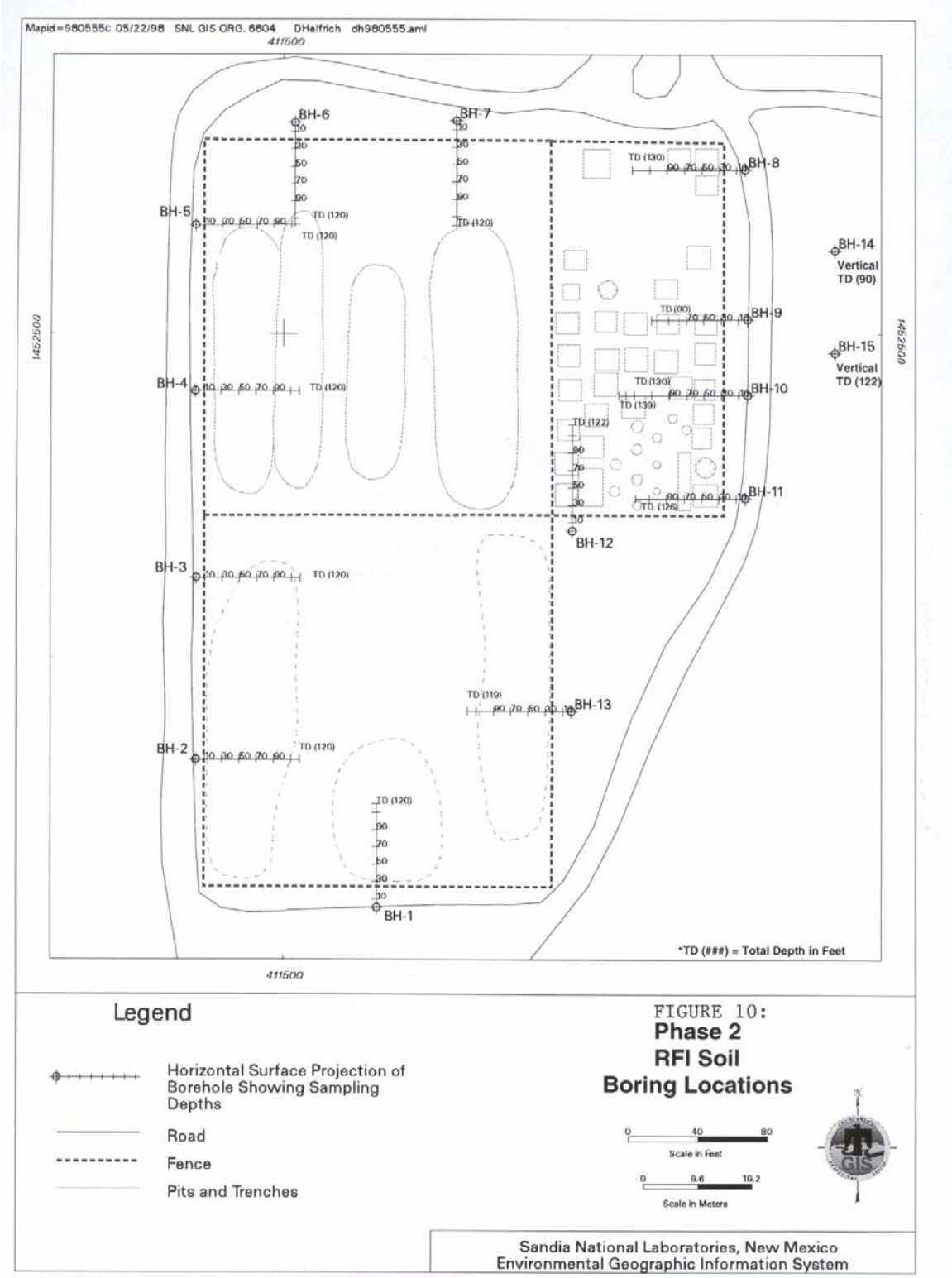
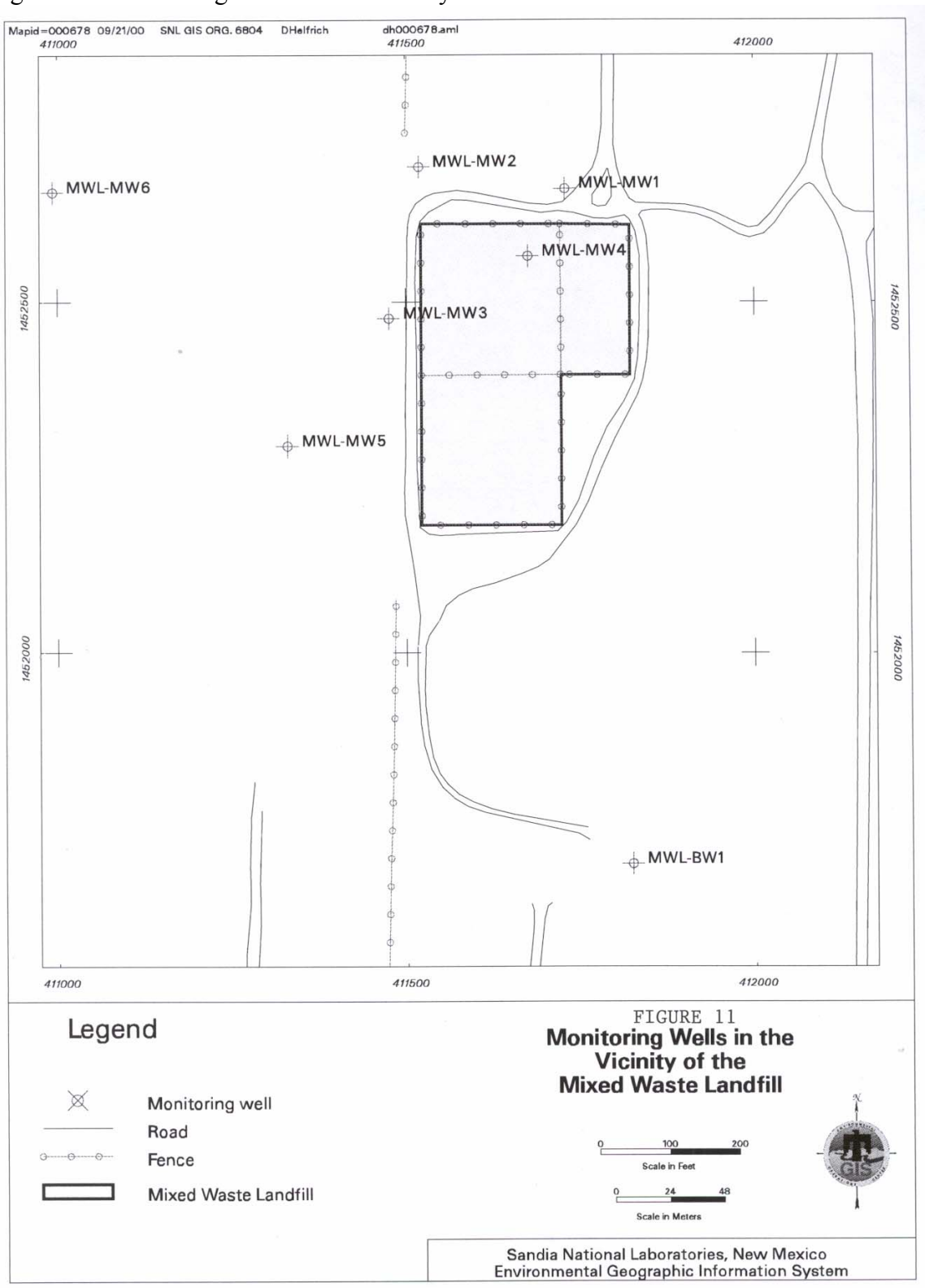


Figure 11: Monitoring Wells in the Vicinity of the Mixed Waste Landfill



3.0 Peer Review Process

The formal peer review of Sandia's MWL was conducted at two separate meetings. On March 22 and 23, 2001 an open public meetings were held at the Doubletree Inn in Albuquerque, New Mexico. A second open public meeting of the peer panel was held on May 11, 2001 at the same location. Prior to these peer panel meetings, a separate meeting was held at the University of New Mexico in Albuquerque on March 6 and 7, 2001 to discuss the process with the public; no peer panel members attended this session. The advertisements for these meetings were published in the Albuquerque Journal and Albuquerque Tribune and are reproduced in Appendix C. The first meeting was to describe the process, the role of WERC, and to gather public input. During the two actual peer review meetings, full and frank discussions between the peer reviewers and the original performers of the work occurred. The initial peer panel meeting (March 22 and 23) reviewed information on the site, historic waste inventory, soil and hydrologic information, characterization data, and critiques of DOE's work. A tour of the site was also made during this meeting. At the second peer panel meeting (May 11) the peer panel presented their initial findings and conclusions, and directed specific questions to DOE and Sandia National Laboratories representatives. A Draft MWL Peer Review report was prepared based on these meetings. This report was made available to the public and DOE/Sandia in hard copy and through the Internet at www.werc.net on July 9, 2001. A public meeting to receive comments on the draft report was held on August 16, 2001. Comments received were used to help the panel complete the final report. An addendum to this document will be made available by September 30, 2001 that responses to each comment received.

DOE's basic components of the proposed action for the MWL presented to the peer panel, as described by their representatives, are:

1) The Mixed Waste Landfill at Sandia National Laboratories is not a threat to human health and environment if left undisturbed; at least for the next several decades. Greatest risk is to workers from high activity waste, principally cobalt 60, if retrieval is used. In the future, this risk will be much less because of natural decay. Table 1 provides a listing of the radionuclides present in the MWL, their respective half-life in years, the estimated total Curie levels in 1989 (6,736 Ci), in 1999 (2,971 Ci), in 2009 (1,560 Ci), in 2019 (933 Ci), 2029 (608 Ci), in 2039 (419 Ci), and so on through the year 2289.

2) To provide an extra layer of protection from erosion and infiltration, DOE's plan is to place a 3-foot-thick vegetative cover with up to 40 inches of sub-grade for purposes of leveling the site with the site monitored for the next 30 to 40 years.

3) At this future date (30 to 40 years) the decision process should be reopened to investigate and identify a final solution.

Panel members performed their evaluation of the MWL based on the four factors presented below, with a lead panel member responsible for each factor. The peer panel reports (presented in Section 4.0 trough 7.0) were completed by a single panel member with input from the whole panel and represent the principal observations/conclusions drawn by the peer panel. Section 8.0 summarizes their findings.

- Fate and transport in all media;
- Short-term and long-term performance;
- Radioactive and hazardous waste/health physics; and
- Analytical/radiochemistry and measurement errors

To evaluation each of these factors the following six criteria were used:

1) Validity of assumptions

2) Alternative interpretations

3) Uncertainty of results and consequences if wrong

4) Appropriateness and limitations of methodology and procedures

5) Accuracy of calculations

6) Validity of calculations

The intent of the peer review was to assess the validity of the assumptions that were used by DOE to evaluate historic performance of the MWL and its safety. As stated earlier, an engineering evaluation of the cover design itself was not a part of this peer review. Additionally, the peer review was not to assess the appropriateness of DOE's historic or existing waste disposal practices, nor future missions or uses at Sandia National Laboratories. The review conducted was a high-level analysis, focused on determining the reasonableness of conclusions reached by DOE. The intent of the review was not to reproduce the calculations and results of the reports used to evaluate the MWL.

Table 1: Radionuclides Present in the Mixed Waste Landfill and Estimated Curie Levels Over Time

Radionuclide	Half-Life (years)	Estimated Ci in 1989	Estimated Ci in 1999	Estimated Ci in 2009	Estimated Ci in 2019	Estimated Ci in 2029	Estimated Ci in 2039	Estimated Ci in 2049	Estimated Ci in 2059	Estimated Ci in 2089	Estimated Ci in 2189	Estimated Ci in 2289
	Year >>	1989	1999	2009	2019	2029	2039	2049	2059	2089	2189	2289
Co-60	5.27	3500	939.7	252.3	67.7	18.2	4.9	1.3	0.4	0.0	0.0	0.0
H-3	12.30	2400	1366.2	777.7	442.7	252.0	143.5	81.7	46.5	8.6	0.0	0.0
Sr-90	29.10	410	323.1	254.6	200.7	158.2	124.6	98.2	77.4	37.9	3.5	0.3
Cs-137	30.17	410	325.9	259.0	205.8	163.6	130.0	103.3	82.1	41.2	4.1	0.4
Pu-238	87.70	1.2E-03	1.1E-03	1.0E-03	9.5E-04	8.7E-04	8.1E-04	7.5E-04	6.9E-04	5.4E-04	2.5E-04	1.1E-04
Am-241	432.00	1.2E-03	1.2E-03	1.2E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.0E-03	8.7E-04	7.4E-04
Ra-226	1602.00	6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.7	5.5	5.3
Pu-239	24100.00	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03
U-238	4470000000.00	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Th-232	14000000000.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
al Ci in Future Years		6736	2971	1560	933	608	419	301	223	104	23	16

4.0 Fate and Transport

Review of the fate and transport of contaminants from the Sandia National Laboratories Mixed Waste Landfill was performed by Dr. Catherine Aimone-Martin, Professor of Mineral Engineering, New Mexico Institute of Mining and Technology. Other panel members contributed their findings in this area during the public meetings.

4.1 Introduction

Fate and transport of contaminants were addressed to evaluate the validity of sampled values (in terms of concentrations or activities) found in the MWL near-environment (chiefly soils and water) and presented in various reports and documents used in the review process. After careful review of the contaminants at the site and considering the nature and extent of releases, it was concluded that tritium is the primary contaminant for consideration. Furthermore, tritium can be used to develop a simplified model of transport to explain the sampled spatial distribution of contaminants with time based on its high mobility and pervasiveness in many forms (liquid and vapor phases).

Tritium was used as the representative contaminant to model transport from the sources within the classified area pits (where most of the tritium was buried) because it is the most mobile and is the only contaminant that was found outside the MWL. The fate and transport of other radionuclides and nonradiological soil/water contaminants have not been considered in this analysis.

A simplified analysis was conducted to address three questions:

- Can the spatial and temporal distribution of tritium that has existed at the site be explained by modeling known levels of tritium inventory, assumed transport processes, and behavior of tritium in the environment/pathways?

- Can the same modeling process be used to predict near-future (the next 10 years) distributions of tritium in the vicinity of the MWL?

- Are current and future expected distributions of tritium activities of such levels to justify leaving the MWL in place?

The results of modeling presented herein were used to verify the assumptions made by Sandia National Laboratories researchers in their decision to cap the MWL.

4.2 Possible Transport Processes at the MWL

A conceptual model of tritium transport at the MWL was first considered prior to modeling. Migration pathways were identified and appropriate transport parameters applicable to the MWL environment were selected from the literature or from direct test results.

Primary transport processes include water vapor diffusion and unsaturated water migration in the form of a surface film on hydrated soil particles. Vapor transport from the source is highly likely in all directions. Downward migration is possible based on temperature-driven (based on diurnal fluctuations of temperature in the above-ground atmosphere relative to the subsurface environment) and pressure-driven transport (e.g. atmospheric pumping). Upward and lateral movement is driven by both vapor pressure and vapor concentration gradients. Vapor transport of tritium in the near-surface environment (to at least 10 to 15 ft. in depth) is likely to be the chief method of migration in granular soils with non-clay fines at low moisture contents (less than 2 to 3 % by weight).

Unsaturated flow of infiltrated atmospheric water can also provide transportation of tritium in all soil types present at the MWL site. Within near-surface non-clay soils with large, air-filled pores and low moisture contents, tritium water migration can take place within the surface film formed on hydrated soil particles. Upward migration most likely is the dominant direction, driven by a moderately negative matric potential (on the order of 1 –3 bars) pressure (1, 2). Lateral migration due to mass flow is expected to be limited.

Unsaturated flow in clay soils (granular soils with some clay fines) of moderate moisture content (around 3 to 10%) can take place in both the air-filled and water-filled pores. Lateral migration based on advection/dispersion can occur, depending on moisture content. Bulk flow can also preferentially take place in fine, water-filled pores according to Darcy's Law. Diffusion of tritium from regions of high to low concentrations is most likely localized (on the order of a few feet) but over time can account for observed anisotropy in concentration plumes. This is particularly true for highly stratified soils with wide variations in horizontal hydraulic conductivity relative to the conductivity in the vertical direction. Migration can take place laterally (as described above), in an upward direction, based on pressure gradients: from low to high capillary tension, and downward based on gravity.

4.3 Transport Modeling Methodology

The transport of tritium was modeled using GoldSim® (3). GoldSim® is a generalized object-oriented probabilistic spreadsheet that enables add-in computational modules. One such module comprises finite difference equations describing transport processes. GoldSim® was used to model tritium contaminant concentrations and fluxes at various locations over time for the MWL by considering mass transport from a source (inventory), release mechanisms, transport processes and migration pathways. In addition, the effect of radionuclide decay was considered.

Mixing cells within the transport medium (soils) were dynamically linked in time with finite difference equations describing the movement of tritium by various transport processes. The program was used to compute the tritium concentrations found in soil samples using data provided in Sandia National Laboratories reports. The objective of the modeling was to conservatively arrive at the most recent sampled levels of tritium activity.

Mr. Bruce Baker, Computer Engineer with Technadyne (Albuquerque) designed the model for this analysis and conducted the various runs to obtain the simulations. Mr. Baker donated his time on this review during model training exercises in building simulations.

Background information and relevant parameters used for this analysis as well as assumption made in the modeling are outlined below.

4.3.1 Background Information for Modeling

- Results of borehole and surface soil sampling programs were used as a target for initial and final modeling. These data are presented in the 1989-1990 (4) and 1994-1995 (5) sampling programs. Final modeling runs were made using the 1994-95 data set only, specifically data from boreholes BH-9 and BH-12.

- The inventory was proportioned among the classified area pits assumed to be 10 ft. in diameter and 25 ft. deep according to the inventory values contained in published documents. The inventory was spatially located according to actual pit locations (see Figure 9). Pit 33 contained the bulk of the initial inventory (822 Ci), followed by pits 26 (88.5 Ci), 22/27 (81 Ci), 25 (76.5 Ci), 16 (75 Ci), 24 (60 Ci), 19 (60 Ci), 32 (55.6 Ci), 18 (45 Ci), 15 (30 Ci), 21 (30 Ci), and 31 (27.7 Ci). Remaining inventories, not specifically accounted for in these pits were assigned to two additional pits (A and B). The location of these pits was unspecified; however, they were necessary to include in the modeling process.

- Classified area source pits 33 and 25 were used to model the vertical distribution of tritium over time. Subsurface tritium activities below these two pits were computed in "mixing cells", 10 feet (ft.) in diameter and 10 ft. in thickness, starting at a depth of 30 ft. (the "center" of the first cell), and for every 10 ft. (e.g. 40, 50, 60, 70 ft, etc.) to a total depth of 90 ft. These mixing cells are defined as computational cells for modeling purposes.

- Inventory maps and records were used to determine the distribution of tritium sources. It was assumed that a total tritium source of 2,400 Ci was placed in the classified area pits 30 years ago.

- The inventory was encased in 400 mil plastic bags and allowed to release at a prescribed rate over 40 years. The first 30 years represents present day while the additional 10 years represents a point in time 10 years forward. Simultaneously, the inventory and concentration released were decayed at the half-life rate for tritium.

4.3.2 Modeling assumptions

- Migration pathway – The model was first run to limit migration to the vertical direction. Subsequent modeling was made to simulate only horizontal migration to determine a horizontal advection factor applied to spatial vertical data.

- The model was run for a total for 40 years to explain the existing subsurface activities at year 30 (assumed current point in time) and forward for 10 years (for predictive purposes).

- Subsurface tritium activities were computed in "mixing cells", 10 ft. in diameter and in thickness, starting at 30 ft. in depth (the "center" of the first cell), and for every 10 ft. (e.g. 40, 50, etc.) to a total depth of 70 or 80 ft. The layout of these mixing cells is shown in Figure 12 in which row 1 represents 30 ft. and row 5 represents 80 ft.

- Hydrological and soil parameters assumed include:

		Source
unsaturated hydraulic conductivity	5×10^{-7} centimeters/second	(5)
volumetric water content	10 %	(6) (7)
diffusivity	1×10^{-9} meters^2/second	(3) (6)
soil bulk density	1.5 grams/cubic centimeter (g/cc)*	(5)

* Average value for all boreholes was 1.92 g/cc; however the value for the borehole modeled was 1.38 g/cc, therefore 1.5 g/cc is a conservative average.

- The total inventory is assumed to be contained in 100 "packets" that represent 100% of the initial inventory. A packet is defined within the GoldSim® model as a unit of measure of the total source volume. Fifty-percent (50%) of the packets were failed between 0 and 40 years. This effectively releases

$$[(0.5) * (2{,}400 \text{ Ci} - \text{inventory})] / (9{,}696 \text{ Ci/gram}) = 0.124 \text{ grams of tritium}$$

where 0.248 grams of tritium represent the total inventory. This provides a reasonable release scenario, allowing for natural decay of the remaining 0.124 grams of tritium.

4.3.3 Implementation of Model

The modeling was accomplished in three steps. The first step, or the vertical case, involved computing the expected tritium activities in the soil moisture as a function of depth below representative burial pits to verify the input parameters used. Predicted tritium concentrations were calculated over a 40-year time period for mixing (computational) cells between 30 ft. and 90 ft. below the ground surface. The orders of magnitudes of predicted concentrations were compared to sampled values taken from borehole samples during 1994-95 and 1989-90 to determine if the numbers were in agreement.

The second step, or the horizontal case, involved computing the expected concentration values at a 30 ft. depth (or the same depth as the first "mixing" cell) for 10 ft. by 10 ft. "regions" in between classified area pits, as shown in the plan view of a portion of the classified area in Figure 13. The concentration in various regions, labeled by column and row (e.g. column 5, rows 9, 10, and 11) was computed assuming horizontal flow as shown by the arrows.

The relative values of concentration as a function of time were computed and compared between adjacent "regions", downstream from a "source" burial pit, to obtain a nominal horizontal diffusion factor. The diffusion factor was applied to the vertical concentrations calculated at depth (from the vertical case) for the 10 ft. by 10 ft. "regions" that were located laterally from a burial pit vertical centerline (e.g. cell 24 in this example).

The third and final step involved computing tritium concentrations for cell centers representing borehole soil sample locations. Inclined boreholes BH-9 and BH-12, from the 1994-95 sampling program, were used and pits 33 and 25 selected as the burial sources having the greatest spatial and temporal influence on mixing cell concentrations. Tritium concentrations as a function of depth were computed and a horizontal diffusion ("reduction") factor was applied in a manner proportional to the net horizontal distance from the source cell center. An example of this procedure is given for the 10 ft. by 10 ft. regions (labeled "a" and "b") shown in Figure 14 lateral to an arbitrary source pit "X".

Assuming flow is taking place from the right to the left, the "net" concentration in lateral region "a" is computed as

(concentration in the mixing cell at 50 ft.) * (1-diffusion factor)

The net concentration in lateral region "b" is computed as

(concentration in the region "a") * (1-diffusion factor)

and so forth.

4.3.4 Modeling Results

The following plots are provided as examples of the typical output from GoldSim® used to predict tritium concentration at soil sample locations in BH-9 and BH-12. Figure 15 shows the unexposed mass of tritium remaining in the inventory over the 40-year modeling period (time is in years).

Figures 16 and 17 show the advective concentration (in mg/L, computed from the inventory release in mg, and knowing the soil bulk density and average moisture content) and diffusive flux (in milligrams/year) for classified area pit 33. In Figure 16, the black line shows the concentration moving vertically out of cell 33 (at 25 ft.) while the remaining lines show concentration moving downward from each mixing cell. In Figure 17, diffusive flux is shown for tritium moving in the soil water from pit 33 to all other burial pits at a depth of 30 ft.

Typical plots used to analyze the horizontal diffusion factor are given in Figures 18 through 20 for the cells immediately to the left of cell 24 shown in Figure 13. Concentration over time is computed for cells at lateral distances of 10, 20 and 30 ft. from cell 24 (rows 11, 10, and 9 shown in Figure 13) at a depth below the ground surface of 30 ft. Using the upper most concentration plots for column 5 (the same column and "up-gradient" of assumed flow direction), the net "reduction" in peak concentration from row 11 to row 10 is approximately 75%. The reduction from row 10 to row 9 is also on the order of 75%. In fact, when this analysis is performed for cells throughout the grid shown in Figure 13, the average horizontal reduction in concentration between all cells is 75%. Therefore, the net concentration remaining becomes 25% (or 100% – 75%) of the concentration in upstream regions. The 25% factor was used to compute the horizontal tritium concentration with time applied to the vertical advective flux.

As the last step in predicting tritium concentrations in boreholes BH-9 and BH-12, advective flux values were computed at a 30-year time period following source burial in mixing cells beneath pits 33 and 25, respectively. The horizontal diffusion concentration factor was applied to values at a rate of 0.25 per 10 ft. of distance away from the source cell center (as described above). As an example, using the geometry defined in Figure 14 and assuming a concentration at the 50 ft. mixing cell of 1.05 (10^{-6}) milligrams/liter (mg/L) of tritium, the "reduced" horizontal concentration values are computed as follows:

region "a" 1.05 (10^{-6}) * 0.25 (1 cell displaced) = 0.2625 (10^{-6}) mg/L of tritium

region "b" 0.2625 (10^{-6}) * 0.25 (1 additional cell displaced) = 0.0656 (10^{-6}) mg/L of tritium

This procedure was repeated for regions adjacent to pits 25 and 33. The results of the calculations for boreholes BH-9 and BH-12 are given in Table 2. The table gives predicted values using GoldSim® and the values obtained by sampling in mg/L of tritium. In all cases, with the exception of the sample at 30 ft. in BH-12, the orders of magnitudes of the predictions are in good agreement with the sampled values.

Apparently, the unusually high sampled value of 0.78 (10^{-6}) mg/L of tritium cannot be replicated by modeling using a subsurface transport process model alone and the simplified assumptions made herein. In such circumstances, there may be other concentrating influences that remain unknown and cannot be modeled. This is reasonable and should be expected in any modeling effort.

Table 2: Results of GoldSim® modeling used to predict borehole tritium sampled data

1994-1995 sampling						
Depth downhole	BH 12 sampled		predicted	BH 9 sampled		predicted
ft.	pCi/L	mg/L (10^{-6})	mg/L (10^{-6})	pCi/L	mg/L (10^{-6})	mg/L (10^{-6})
30	7,800,000	0.78	0.059	46,800	0.00468	0.0034
40			0.061			0.0026
50	210,500	0.02105	0.042	16,600	0.00166	0.0017
60			0.026			0.00079
70	2,580	0.000258	Negl.	14,780	0.001478	Negl.
80						
90	1,480	0.000148		10,570	0.001057	

Negl. – negligible values computed (at or below the detection limits for tritium), Picocuries/L (pCi/L)

It should be pointed out that the predicted value of 0.061(10^{-6}) mg/L at 40 ft. downhole is slightly greater than the value computed at 30 ft. This is due to the spatial locations of the samples relative to the base of pit 25. Borehole BH 12 is inclined 30 degrees toward pit 25 and passes adjacent to and slightly under pit 25 nearer to the 40 ft. sample than the 30 ft. sample. Therefore, at 30 ft., the sample farther removed from the pit base would be expected to show a lower activity.

The predicted values at depth (below 60 ft.) do not appear to match the sampled data as the predicted attenuation of tritium concentration with depth is higher than the data suggest. Hence, the model does not appear to fully take into account other possible transport mechanisms/or controls at depth, where documented physical changes in soil/moisture properties take place (e.g. from silty-sandy, poor moisture retention soils to clayey-silty-sandy, high moisture retention soils). In the modeling process, it is assumed that soil properties do not change with depth. Only the near-surface soils types (with low moisture contents) have been modeled. Therefore, migration of above-background tritium values at depths below 90 ft. should reasonably be predicted using the GoldSim® model for more complicated runs where soil and hydraulic properties are varied with depth. This was, however, beyond the scope of this review and only the near-surface soil types were modeled.

The future concentrations of tritium migration have been assessed in the modeling process. Figures 16 and 17 are used to present the worst-case scenario in predicting the

subsurface concentrations and mass flux with depth over time up to 40 years. It is shown that by considering both diffusion and natural decay of tritium, the concentrations are currently diminishing and should continue to diminish for the next 10 years.

4.4 Conclusions

The data pertaining to fate and transport of tritium from the MWL presented and reviewed in this report (specifically, the spatial and temporal distribution of sampled tritium activities), appear to be consistent with those expected given the inventory, regional meteorology, subsurface soil conditions, and hydrologic parameters.

The modeling results, using GoldSim® to predict tritium concentrations in borehole soil water samples, show good agreement with the 1994-95 subsurface sampling data for the limited range of depth below the surface that the model was intended to simulate. Therefore, the assumptions made by Sandia National Laboratories appear to be valid and can be supported by independent modeling.

The quality of work conducted by Sandia National Laboratories in characterizing the spatial and temporal distribution of tritium from the classified area in the MWL is very good.

Future concentrations of tritium are not expected to increase but rather are expected to decrease over the next 10 years based on the natural decay of the tritium radionuclide.

Section 4.0 References

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2) Phillips, F.M., Mattrick, J.L., and Duval, T.A., Chlorine 36 and Tritium From Nuclear Weapon Fallout as Tracers for Long-Term Liquid and Vapor Movement in Desert Soils, *Water Resources Research*, Vol. 24, No. 11, pp. 1877-1891.

3) GoldSim®, Version 7.14, Golder Associates, Redmond, WA.

4) Phase 2 RCRA Facility Investigation Work Plan for the Mixed Waste Landfill, Environmental Restoration Program, Sandia National Laboratories, March 1993

5) Goering, T.J., McVey, M.D., Strong, W.R., and Peace, J.L., Analysis of Instantaneous Profiles Test Data from Soils Near the Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories/New Mexico, SAND95-1637, August 1995

6) Wolford, R. A., Modeling the Infiltration of Reactor Coolant Water from Trench D at the Mixed Waste Landfill: Sandia National Laboratories, New Mexico. Sandia National Laboratories
Environmental Restoration Project, Albuquerque, NM. March 27, 1997.

7) Roepke, C.S., Strong, W.R., Nguyen, H.A., McVey, M.D., and Goering, T.J. Unsaturated Hydrologic Flow Parameters Based on Laboratory and Field Data For Soils Near the Mixed Waste Landfill, Technical Area III, Sandia National Laboratories/New Mexico, SAND 96-2090, August 1996.

8) Peace, J.L., Goering, T.J., and McVey, M.D., Tritium in Surface Sols at the Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories/New Mexico, SAND95-1611, April1996.

9) Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Environmental Restoration Project Sandia National Laboratories, Albuquerque, New Mexico, September 1996

Figure 12: Physical layout of mixing cells below classified area pits used to model tritium transport using GoldSim®

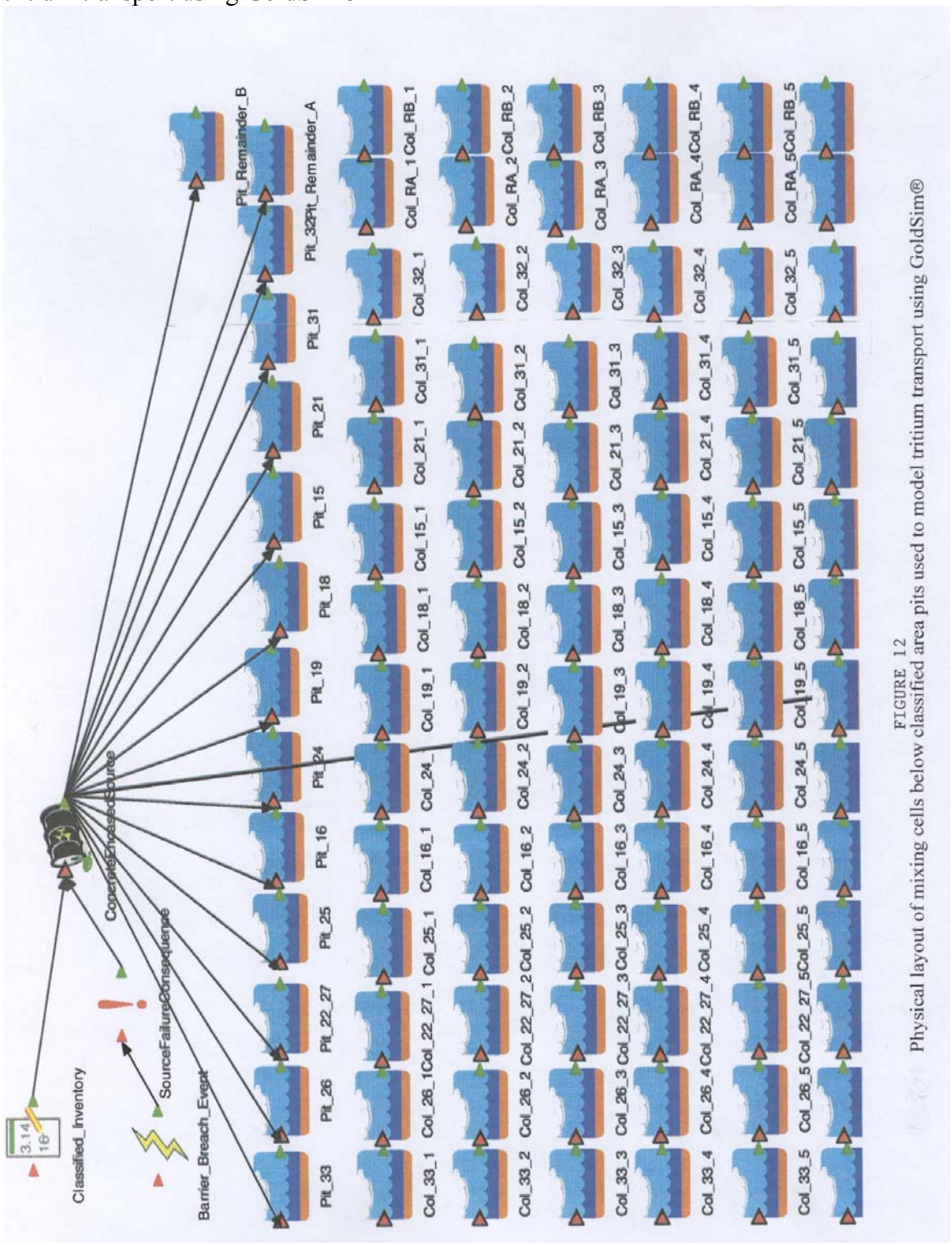

FIGURE 12
Physical layout of mixing cells below classified area pits used to model tritium transport using GoldSim®

Figure 13: Plan view of a section of the classified area showing 10 ft. regions used in horizontal tritium advection calculations between burial pits (numbered)

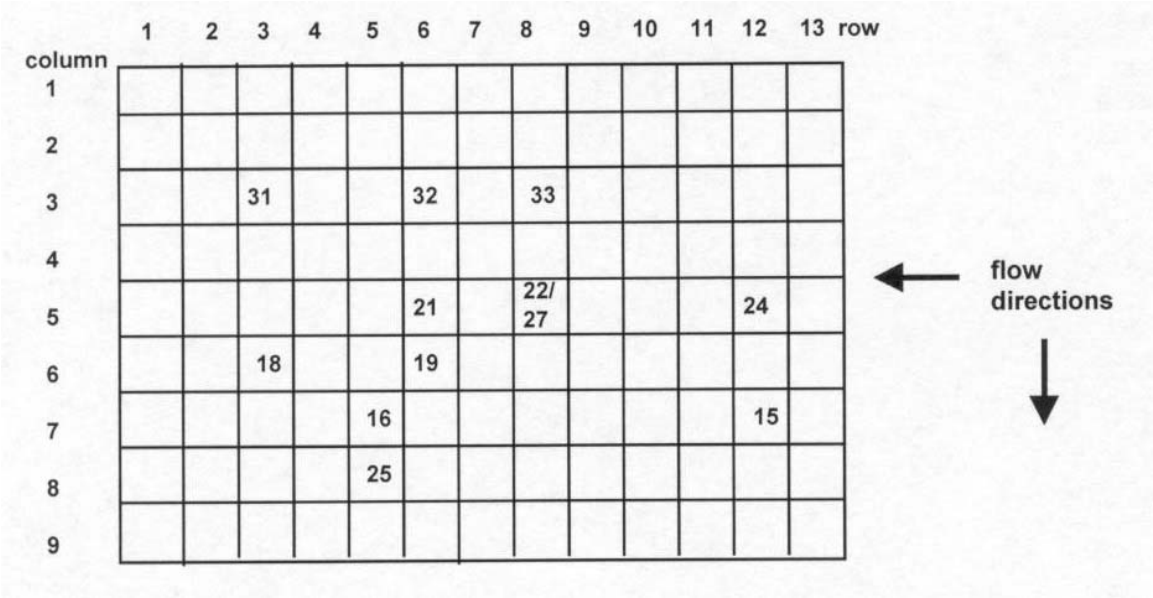

Figure 14: Geometry for example calculation

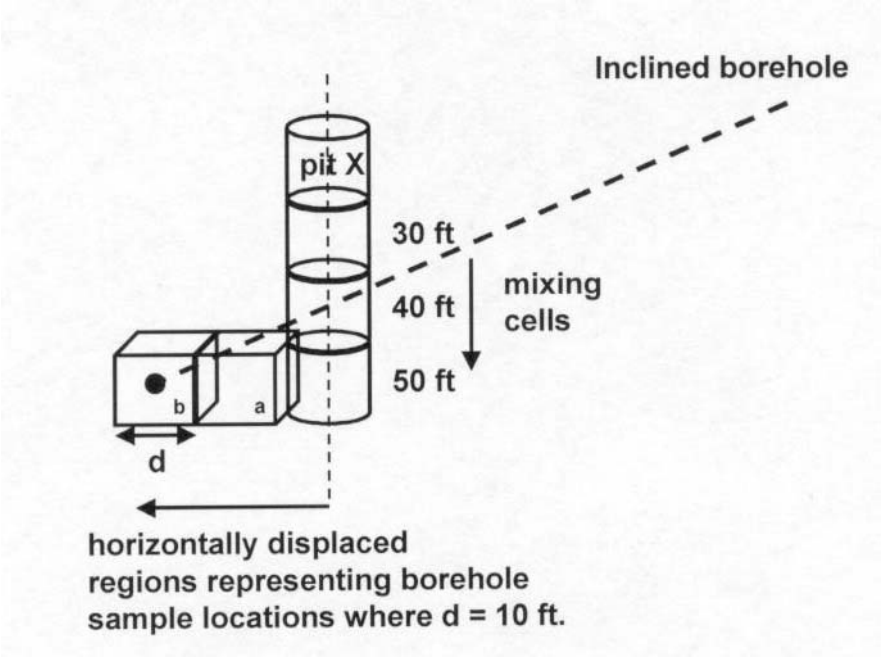

Figure 15: Unexposed tritium mass remaining in the classified area inventory by year over 40 years from burial

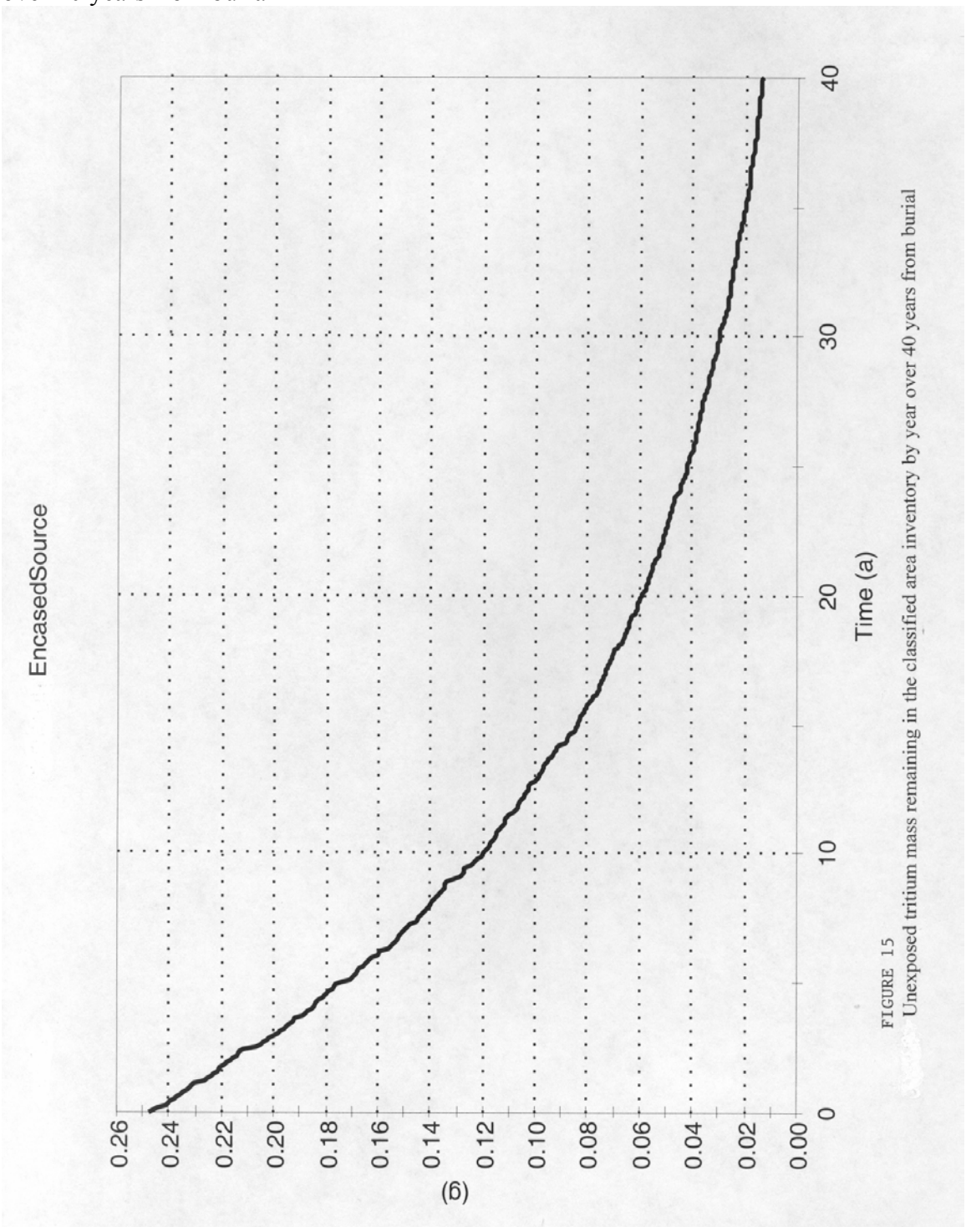

Figure 16: Advective concentrations computed for 40 years in mixing cells beneath classified area pit
33

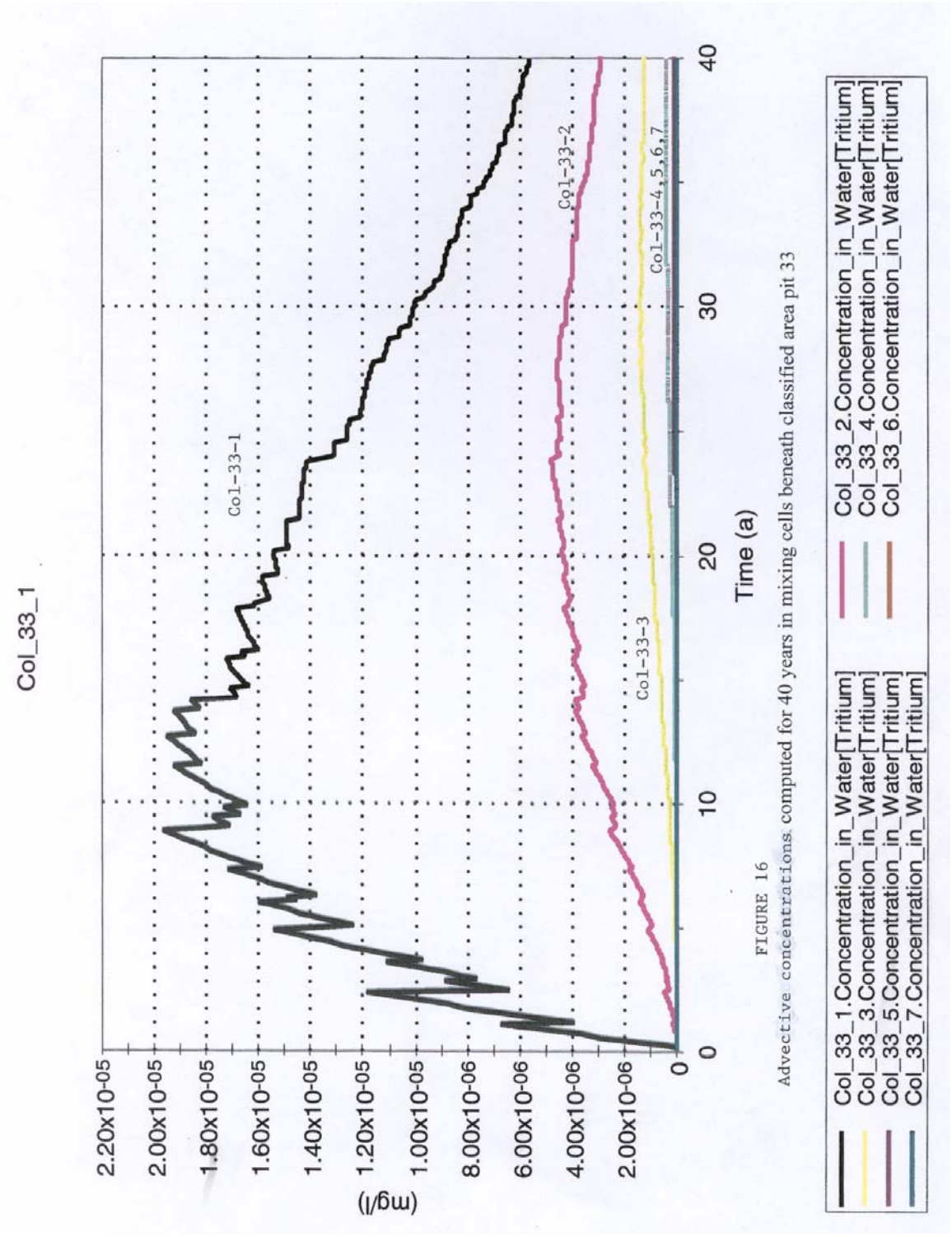

Figure 17: Diffusive mass flux from pit 33 computed at 30ft. in depth for 40 years in mixing cells beneath classified area pits

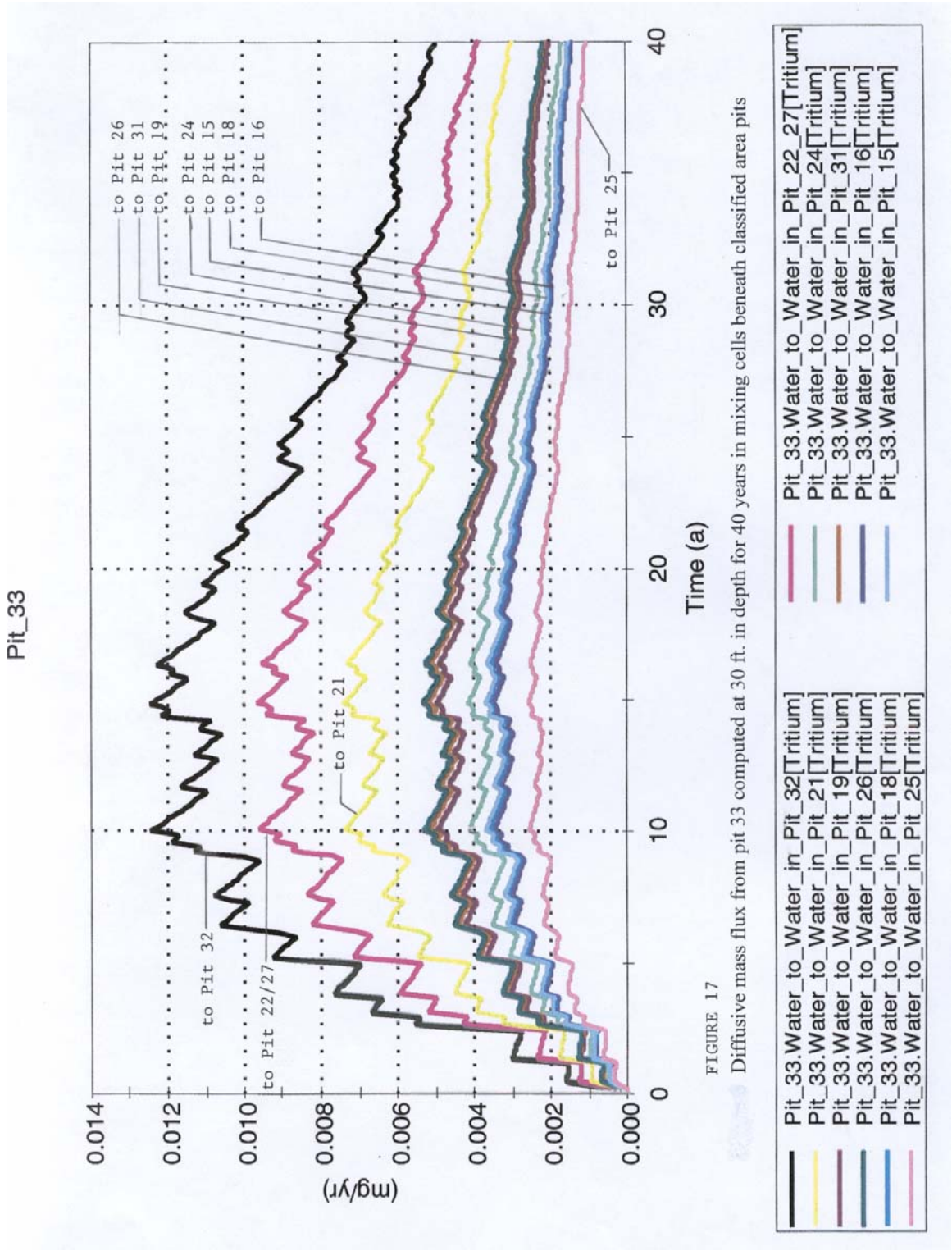

FIGURE 17
Diffusive mass flux from pit 33 computed at 30 ft. in depth for 40 years in mixing cells beneath classified area pits

Figure 18: Tritium concentration over time from pit 24 at 30 ft. from the ground surface in row 11 for all columns (1 through 9 shown in Figure 13); note that concentrations in column 1 through 4 are zero as flow does not take place in this direction

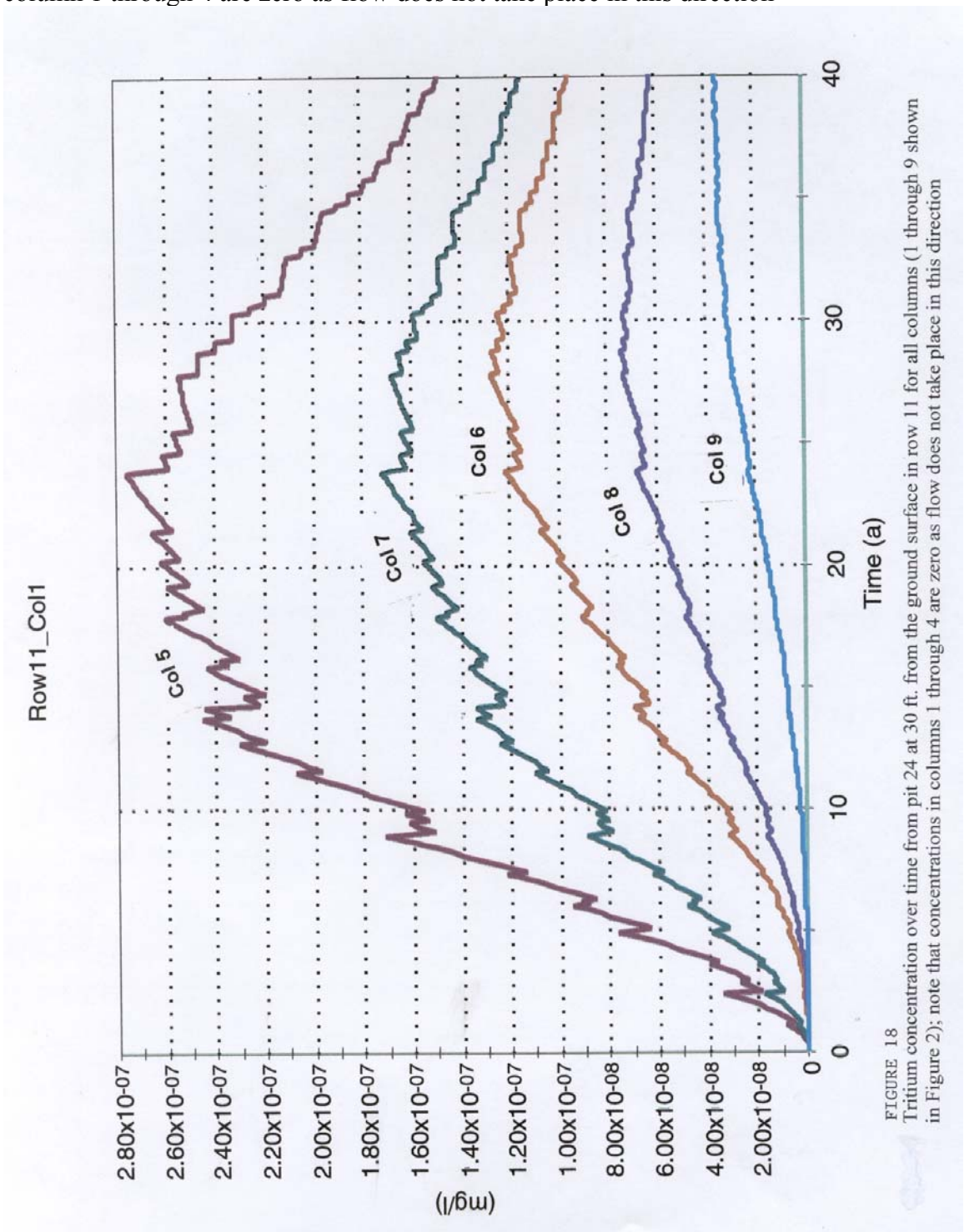

FIGURE 18
Tritium concentration over time from pit 24 at 30 ft. from the ground surface in row 11 for all columns (1 through 9 shown in Figure 2); note that concentrations in columns 1 through 4 are zero as flow does not take place in this direction

Figure 19: Tritium concentration over time from pit 24 at 30 ft. from the ground surface in row 10 for all columns (1 through 9 shown in Figure 13); note that concentrations in column 1 through 4 are zero as flow does not take place in this direction

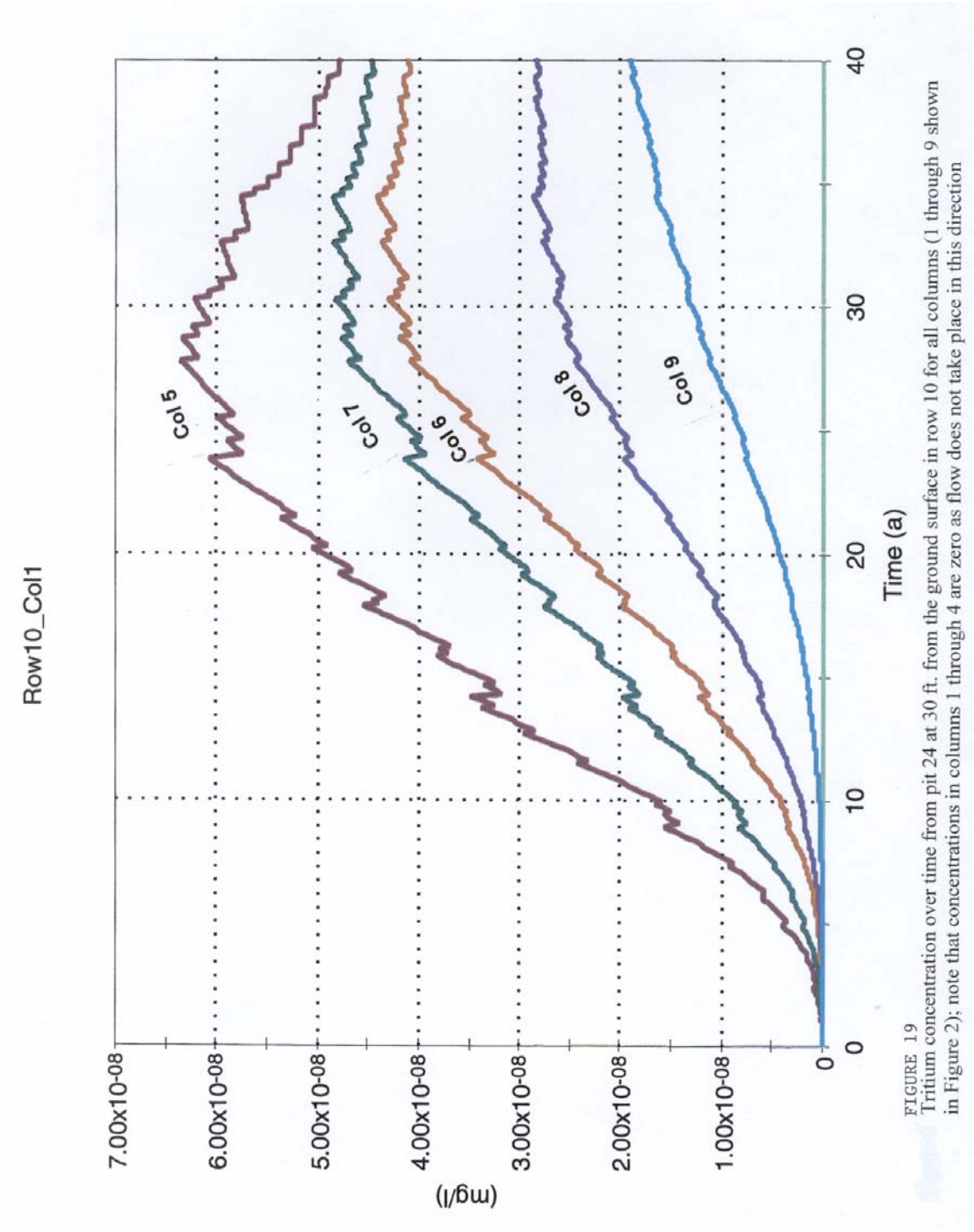

FIGURE 19
Tritium concentration over time from pit 24 at 30 ft. from the ground surface in row 10 for all columns (1 through 9 shown in Figure 2); note that concentrations in columns 1 through 4 are zero as flow does not take place in this direction

Figure 20: Tritium concentration over time from pit 24 at 30 ft. from the ground surface in row 9 for all columns (1 through 9 shown in Figure 13); note that concentrations in column 1 through 4 are zero as flow does not take place in this direction

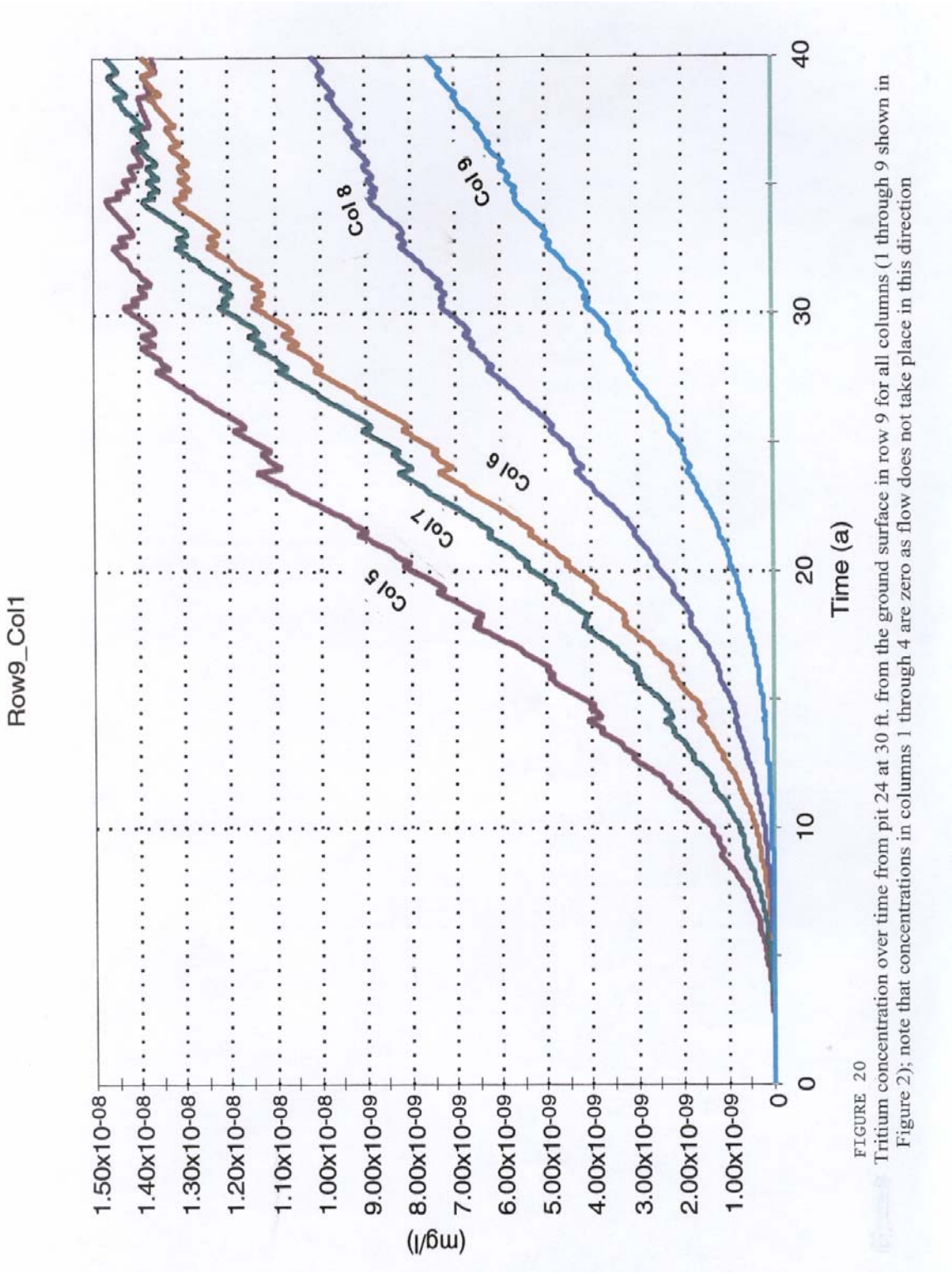

FIGURE 20
Tritium concentration over time from pit 24 at 30 ft. from the ground surface in row 9 for all columns (1 through 9 shown in Figure 2); note that concentrations in columns 1 through 4 are zero as flow does not take place in this direction

5.0 Short-term and Long-term Performance

Review of the short-term and long-term performance characteristics of the Sandia National Laboratories Mixed Waste Landfill was performed by Dr. Eric Nuttall, Professor of Chemical/Nuclear Engineering, University of New Mexico. Other panel members contributed their findings in this area during the public meetings.

5.1 Summary of Short-term and Long-term Performance

The MWL, to the knowledge of the panel, neither resulted in human exposure to contaminants nor resulted in any significant environmental damage. Continuation of monitoring at the site will be essential to determine if there is a potential for change in this status. The MWL is unlined and has no engineered protection at this time from water intrusion. Although located within a secure federally operated site, the actual MWL is protected with a modest fence and very limited warning signs. The nature and amounts of wastes stored at the MWL site plus the location of the site next to a major growing metropolitan city represents a potential hazard to both humans and the environment. If human exposure and/or environmental damage become imminent based on monitoring data, the hazardous/radioactive waste should ultimately be excavated and stored in a licensed repository. It is important to document the economic and environmental impacts associated with how best to excavate, when it is appropriate to excavate, and how to store the radioactive and hazardous waste from the MWL site if required at some future date.

Furthermore, at this time there is a critical need to compile all of the relevant information related to this site in one document series. The cleanup experience at the DOE Hanford, Washington site has shown that such information is invaluable and will save significant future costs and efforts.

5.2 Performance Review

This portion of the WERC review addresses the short- and long-term performance of Sandia National Laboratories MWL. Sources of input include oral presentations on March 22-23 and May 11, 2001 by representatives from Sandia National Laboratories, DOE, New Mexico Environment Department, and Albuquerque Health Department, plus over a hundred documents provided to WERC. The comments are based on the reviewers unbiased professional judgment performed within the time and scope of the review. Based on this review, Sandia National Laboratories appears to have proceeded in a timely and professional manner in their investigation of this site. The investigation began shortly after closure in 1988 and has continued until the present. During this time Sandia has spent 10 to 12 million dollars in characterizing the site and in efforts to obtain permits as well as addressing concerns by the New Mexico Environment Department, advisory groups, citizens, and others. With respect to this peer review, Sandia National

Laboratories has been very responsive in this effort and very forthcoming with information and explanations to issues of concern.

5.3 Issues

The Baskaran, *Mixed Waste Landfill Review* of July 5, 2000, in part, prompted a principal motivation for this peer review. During this review several of the concerns and claims made in the Baskaran report were addressed as well as new issues brought forth. These included the following:

1. Source concerns—accelerated release in the future
2. Increased degradation of source canisters with time and accelerated release
3. Episodic influx of water—thunderstorms, desert floods, etc.
4. Intrusion (human, utility lines, roads, construction, plants, animal, etc.)
5. Tritium migration
6. Large quantities of toxic metals, depleted uranium, lead
7. Many radionuclides, Co, H-3,U, Pu, Am, Cs, Sr, Ra, etc.
8. Concerns for waste removal and storage
9. Reactor coolant water discharge

5.3.1 Issue 1: Source concerns—accelerated release in the future

The MWL contains large quantities of radionuclides and hazardous materials (see inventory list in Appendix B) including metallic lead and metallic depleted uranium (DU). Migration of tritium has occurred outside of the current boundaries by hundreds of feet and to depths of at least 100 ft. DOE's Handford experience has shown that waste often finds means and mechanisms for extensive migration into the environment and that good documentation of inventory and site operation is very helpful to future remediation efforts. An interesting point is that the MWL waste in general appears to meet the criteria for disposal at the WIPP site (Waste Isolation Pilot Plant) though there may be some exceptions.

5.3.2 Issue 2: Increased degradation of source canisters with time and accelerated release

The waste in the trenches was generally enclosed in plastic containers, fiberboard, cardboard, wooden crates, and plastic bags as illustrated in Figures 4, 6, and 8. Also hundreds of 55-gallon drums of waste were disposed in the trenches as shown in Figure 5. In the future these container materials will likely deteriorate and make radionuclides and hazardous waste more accessible to the environment (including plants and rodents), and to migrate beyond the immediate landfill. Though the short half-life radionuclides will show significant decay (e.g., cobalt-60 at 5.27 years, tritium at 12.5 years), many other long half-life nuclides will not; such as cesium, strontium, uranium, and plutonium.

5.3.3 Issue 3: Episodic influx of water—thunderstorms, desert floods, etc.

Though the water table is 500 ft below ground surface and recharge of water from average rainfall is unlikely, New Mexico and the Sandia area often receive heavy thunderstorms and desert floods. To date much of the waste has been protected in plastic containers and plastic bags; however, these will likely deteriorate over time and provide a potential source for migration via water intrusions. Recent experience by DOE has shown that engineered caps/covers often leak and permit migration of radionuclides into ground water, as is the case with many uranium mill tailing disposal cells. The combination of rodents and ponding creates a mechanism for contaminant migration. Sandia National Laboratories stated that current engineered caps/covers are often not adequate. If a cap is to be placed on the MWL as a temporary measure its design needs to address these concerns.

5.3.4 Issue 4: Intrusion (human, utility lines, roads, construction, plants, animal, etc.)

The MWL, at this time is unlined, has no engineered protection from water intrusion, and is protected with only a modest fence and very limited warning signs. The nature and amounts of hazardous and radioactive materials stored at the MWL site plus the location of the site next to a major growing metropolitan city represents a long-term potential hazard to both humans and the environment. Although there is significant security at the site surrounding the MWL, it is plausible that the site, as it exists today, could be subject to human intrusions and thus unnecessary exposure to contaminants. In addition to the potential for human intrusion there is a clear concern for intrusion by animals and plants. Though this is a desert region there is considerable activity by rodents, snakes, etc. as well as the potential for plant uptake of the contaminants such as the soluabilized depleted uranium and lead.

5.3.5 Issue 5: Tritium and its migration

Tritium is of particular concern because it combines to form radioactive water and thus, behaves in the same way. Tritium will migrate both as a vapor and as radioactive water with no retardation. Tritium passes through the skin and is inhaled into the lungs. In the

human body it behaves as water going into the cells and in the formation of tissue. Recognizing this risk, EPA regulates tritium in drinking water to a maximum concentration limit of 20,000 pCi/L.

Soil and pore water sampling has shown that tritium has migrated outside the current MWL boundaries as shown in Figures 21 and 22. The modeling of the fate and transport of this contaminant is presented in Section 4.0 of this report.

5.3.6 Issue 6: Large quantities of toxic metals, depleted uranium, lead

The MLW contains tons of metallic depleted uranium and lead. Both uranium and lead present a major health hazard to humans. EPA's maximum concentration limit in drinking water for uranium is 44 parts per billion (ppb) and 15 ppb for lead. Both materials are subject to oxidation and soluabilization in water. Currently, they have not been detected at levels in the soil and groundwater to cause risk to human health or the environment (see Section 6.0). They would, however, be of concern if human intrusion were to occur into the MWL.

5.3.7 Issue 7: Many radionuclides, Co, H-3, U, Pu, Am, Cs, Sr, Ra, etc.

Only two of the suites of radionuclides that are in large quantities have relative short half-life (cobalt-60 at 5.27 years, tritium at 12.3 years). The half-lives of others are presented in Table 1.

The high radioactivity of cobalt-60 is assumed by some to be a problem limiting the near term excavation of the MWL due to worker exposure. This is not likely to be the case. First, all the cobalt-60 sources were encapsulated in lead shielding. Secondarily, because of the relatively short half-life (5.27 years), most of the cobalt-60 has decayed to harmless none radioactive Ni-60. As indicated in the remarks by a Sandia National Laboratories representative (see Section 5.3.8), the problem is mostly one of logistics, i.e., . . . "cobalt-60 sources are encapsulated in two truckloads of concrete plus lead and steel. These are too large to move and DOE's Nevada site has specific waste acceptance criteria restrictions on sealed sources."

5.3.8 Issue 8: Concerns for waste removal and storage

Information provided by Sandia National Laboratories on May 18, 2001is outlined in the following indented section and indicate that:

- Radium-226/beryllium sources are located in 7 or more different pits or trenches.

- Large quantities of lithium targets are located in 4 or more different pits or trenches. While the lithium itself is not radioactive, the targets do contain tritium and other radioactive nuclides.

- Cs-137 spark gap tubes have radioactivity levels that exceed Envirocare's waste acceptance criteria and the DOE's Nevada site won't accept these materials in their present form. These electronic components also contain hazardous wastes.

- Cobalt-60 sources are encapsulated in two truckloads of concrete plus lead and steel. These are too large to move and DOE's Nevada site has specific waste acceptance criteria restrictions on sealed sources.

In addition to the items listed above, which have no viable disposal pathway, the items listed below would pose severe health risks to any workers at the excavation and to anyone repackaging these items for future storage or shipment for disposal. Additionally, if these items were also found to be radioactive (mixed-waste), then there would be no disposal pathway option available.

- Beryllium (Be) catcher with DU is a problem. Be has high biological sensitivity per recent DOE health studies and, therefore, there is a high level of concern today in handling Be.

- Erbium Tritide powder is very ignitable if exposed to liquids.

- Several pits/trenches have oils/solvents sorbed on vermiculite in A/N cans. Treatment facilities won't handle these items because the vermiculite cannot be incinerated. If there is radioactivity present, there is no viable disposal pathway.

One major problem is that there is no way of knowing what wastes have come into contact with others, and any mixing would be very problematic. One thing that has been learned by Sandia National Laboratories from the excavation of the Radioactive Waste Landfill, the Classified Waste Landfill, and the Chemical Waste Landfill is that there is always something unexpected that an excavation uncovers. For the MWL, the cost (in terms of dollars or worker risk) is considered by Sandia National Laboratories to be just too high right now. Sandia believes that it doesn't make sense to open the MWL up, exposing the wastes to the air and wind, and to workers. Compounding these problems are the difficult transportation issues and restrictive waste acceptance criteria.

Sandia believes that a decision to open the MWL now, even though it is a well-behaved landfill with no apparent risk to people or the environment, is

> not a good decision. Sandia also doesn't believe that any more studies of the MWL right now would be productive. Right now, with the realities of risk, waste and funding, DOE sees no viability of a decision to excavate now. Their proposal in the Sandia/DOE Long Term Stewardship Plan is that a very comprehensive study be conducted in the year 2040, after many of the short-lived radionuclides have decayed. At that point, there will be a much better understanding of the local economics, the land use (for example Mesa del Sol), the outcome of many years of sampling and analysis, health effects, etc. This study will be used as the basis for a decision to excavate at that point or wait for further decay. Sandia National Laboratories is budgeting $100,000 for the study and expects the study to be quite comprehensive.

These comments by Sandia National Laboratories provide a valuable insight into the complexity of the MWL site. There is a concern however, by this reviewer, with a solution that caps the MWL and monitors it for many decades. During this time it is possible that the contamination could spread and make the restoration more costly. In addition there are the costs of monitoring, capping and ultimate excavation, placement in drums, and shipment to a licensed facility. The question of when, or if, this excavation and offsite storage should take place is beyond the scope of this report. To answer this question, a comprehensive study should be commissioned by the DOE to address the benefits, costs, and risks of near term excavation and offsite storage (0-5years) versus after 25-100 years.

5.3.9 Issue 9: Reactor coolant water discharge

In May/June of 1967, 204,000 gallons of reactor cool water were discharge in Trench D. There has been considerable discussion of this subject for many reasons. Sandia National Laboratories modeling report (Wolford, Ross A., Modeling the Infiltration of Reactor Coolant Water from Trench D at the Mixed Waste Landfill: Sandia National Laboratories, New Mexico, Contract AS-4958, March 27, 1997) surmised that the water could only have migrated 100-120 feet below the surface. The Baskaran report suggested that the assumed area for water influx was far too large and using a simple calculation showed that for a smaller influx area (200 square feet versus 6,313.3 square feet by Sandia) the total pore volume of the vadose zone was substantially less than the volume of water discharged. Mr. Doug Earp, using an extensive geochemical analysis of the monitoring wells, identified that monitoring well MW-4 (which is directly below the north end of Trench D) showed anomalous values for chloride, nitrate and conductivity. Also the water level in monitoring well MW-4 is 20 ft below the surrounding wells. Sandia has provided plausible explanations for the chloride, nitrate, and conductivity data. The variable water level is believed to be caused by the fact that MW-4 taps a different level in the aquifer. Additional explanation of this water level phenomenon would be useful to understand better the nature of the groundwater regime under the MWL.

Given that monitoring well MW-4 is completed in a deeper zone than the surrounding wells and that the reported values for the chloride, nitrate, and conductivity data are within the range of values reported in Kirtland Air Force Base, it is inconclusive as whether reactor coolant water had reached the ground water based on the geochemical analysis by Mr. Doug Earp.

The reviewer performed a series of calculations and analyses to develop a more accurate determination of the likely area of the discharge water influx. The assumptions and results of these calculations are shown here.

1. An influx rate was matched with water discharge to determine maximum possible area coverage. The rate of discharge from a water truck for delivery of 5,000 gallons was used to estimate influx area for a range of influx rates obtained from field data and an expert on this subject. The results suggested an influx area of about 1,200 square feet was very likely. This value also corresponds to the approximate area covered in a recent field simulation of the truck discharge event by Sandia. Given an area of 1,200 square feet and using the Baskaran simplified calculational model, the 204,000 would have only saturated a zone from the surface to a depth of about 100 feet.

2. Photograph of Trench D (see Figure 8) was evaluated by the reviewer and it was estimated that the remaining area available in 1966 for discharge water influx was about 1,200 square feet. This value is estimated using the dimensions of the fence/gate.

3. Other considerations:
   - lateral movement of the water (K_H/K_V is 10 to 100), where K_H equals horizontal hydraulic conductivity and K_V equals vertical hydraulic conductivity
   - an aquitard at 100 feet—The soils become richer in clay/silt at this depth.
   - surface evaporation of the water

The above factors suggest a simple model assuming the volume directly under the influx area is very conservative. In all likelihood some of the 204,000 gallons of discharge water evaporated and there was likely considerable horizontal spreading.

In summary, using an area estimation of 1,200 square feet and reconsidering the variability in the geochemist of the groundwater at Kirtland Air Force Base it is unlikely that the 204,000 of reactor discharge water migrated to the water table.

Figure 21: 1990 Surface Soil Sample Tritium Results for Samples Above Background (Baskaran, *Mixed Waste Landfill Review* of July 5, 2000 derived from Sandia National Laboratories Phase 1 and Phase 2 RCRA RFI reports)

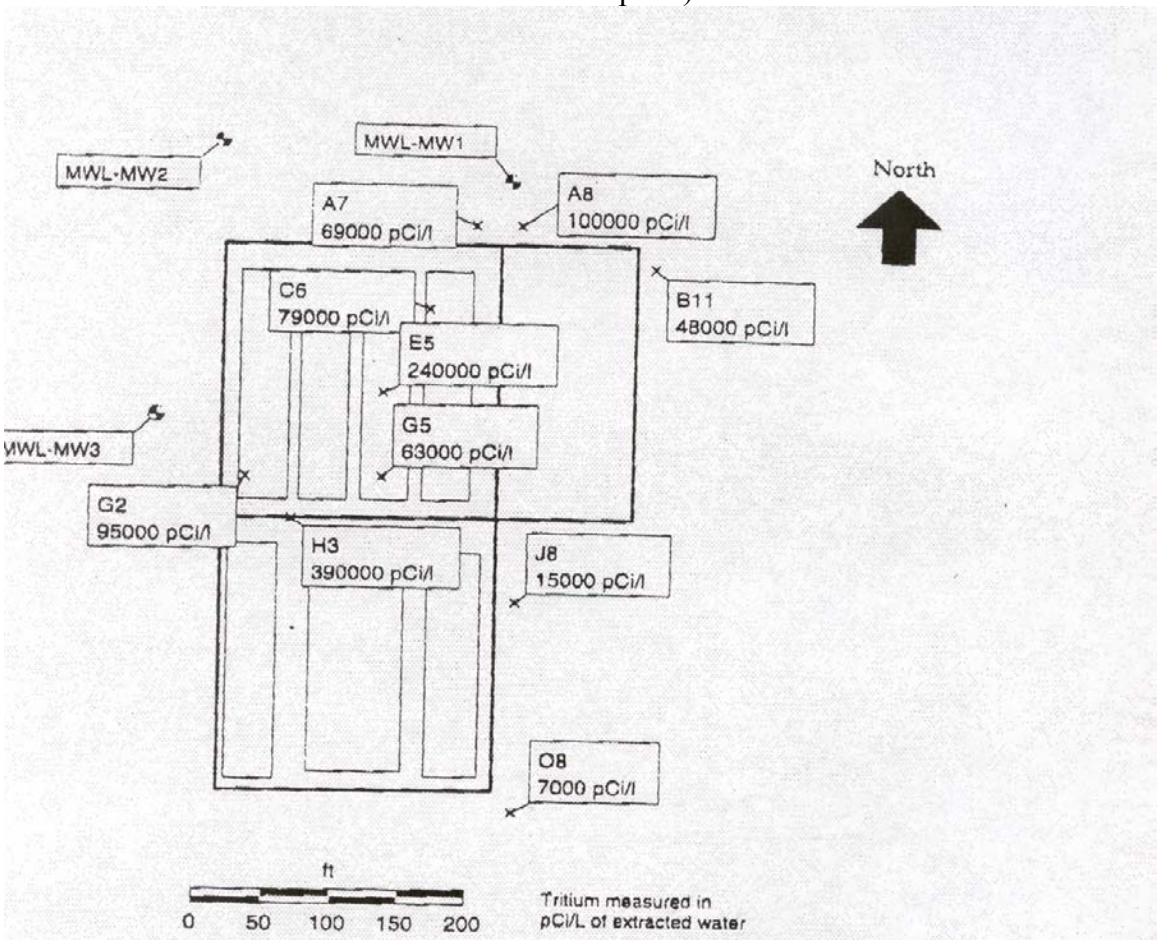

FIGURE 21

1990 Surface Soil Sample Tritium Results for Samples Above Background

(Baskaran, "Mixed Waste Landfill Review", July 5, 2000 derived from Sandia National Laboratories Phase I and Phase 2 RCRA RFI reports)

Figure 22: Location and Depth of Maximum Subsurface Tritium Soil Concentrations Measured in pCi/L of Extracted Water (Baskaran, *Mixed Waste Landfill Review* of July 5, 2000 derived from Sandia National Laboratories Phase 1 and Phase 2 RCRA RFI reports)

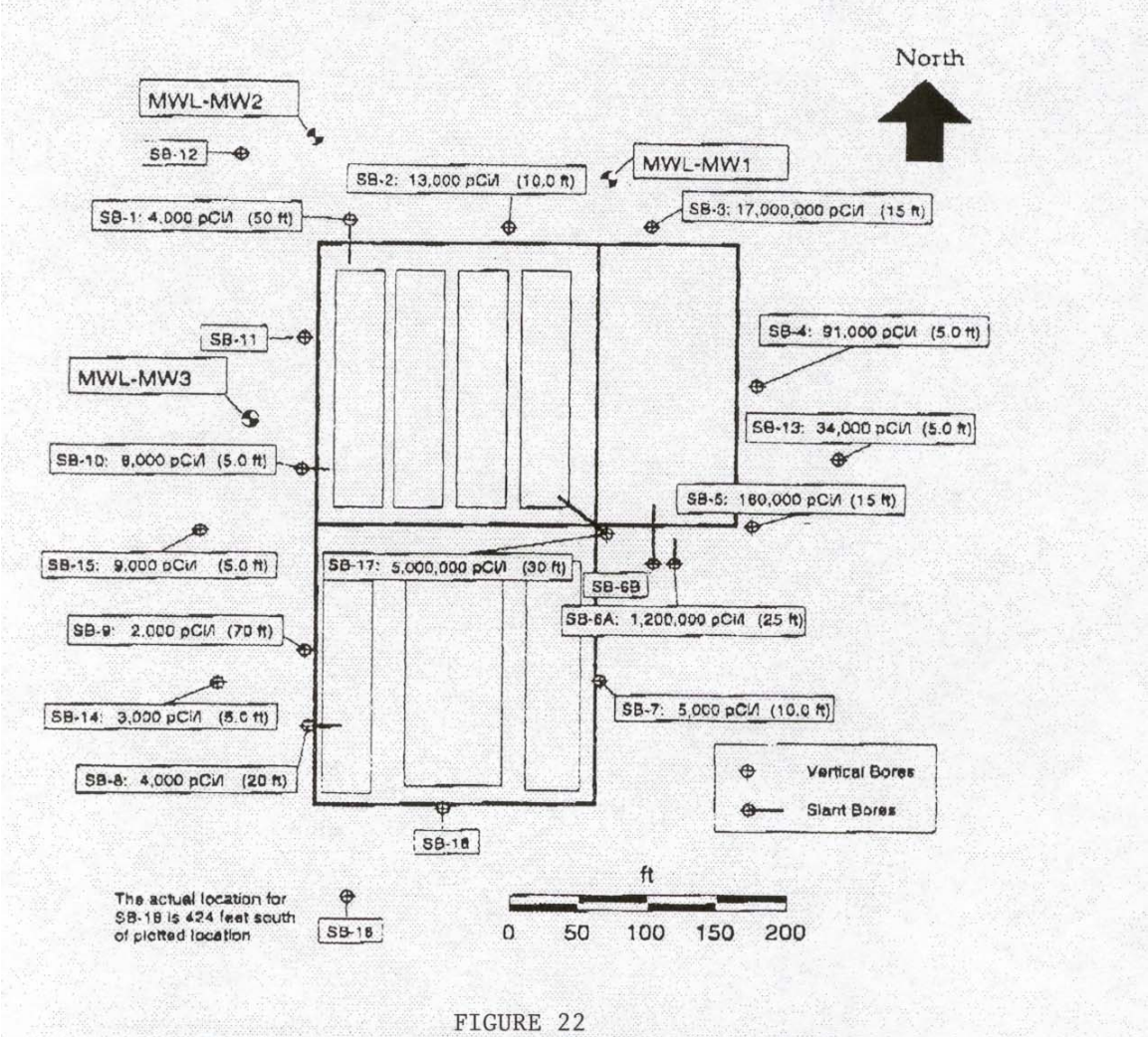

FIGURE 22
Location and Depth of Maximum Subsurface Tritium Soil Concentrations Measured in pCi/L of Extracted Water
(Baskaran, "Mixed Waste Landfill Review", July5, 2000 Derived from Sandia National Laboratories Phase 1 and Phase 2 RCRA RFI reports)

6.0 Evaluation of Human Health and Ecological Risk Screening Assessments

Dr. Mary Walker, Assistant Professor of Pharmacology/Toxicology, University of New Mexico reviewed the radioactive and hazardous waste impacts to human health and the ecology. Other panel members contributed their findings in this area during the public meetings.

6.1 Summary of Evaluation of Human Health Screening Assessment

The human health risk screening assessment for the MWL at the Sandia National Laboratories is adequate and it would appear that the risk posed to human health from radiological and non-radiological contaminants of concern (COCs) is below that requiring action. This conclusion is based on the review of the *SWMU 76: Risk Screening Assessment Report* dated 6/10/1999.

It should be noted that this risk assessment is strictly based on the levels of contaminants that were detected in soil and groundwater sampling. The assessment did not consider risks posed by other chemicals that are present in the MWL, based on the inventory, that have not been released into the environment.

It also should be noted that the document reviewed is intended for an audience of regulators who have been involved in the risk assessment process for 4-5 years and are familiar with previous documents and meetings held prior to the release of this report. Thus, as an outside scientific reviewer without knowledge of this previous process, there are minor items in this report that require clarification: (1) if this report is to serve as a final summary document of the risk assessment process for the outside public and scientific community, and (2) in order to fully understand the risk assessment process that led to the conclusion that the risk posed to human health from radiological and non-radiological COCs is below that requiring action.

6.1.1 Minor Issues Requiring Clarification on the Human Health Screening Assessment

- Since arsenic; methylene chloride; 1,1,2,2-tetrachloroethane; and trichloroethene are the COCs that drive the human health risk assessment, a discussion of these chemicals should be included in section III.4 Extent of Contamination (page 14), rather than simply focusing on tritium.

- Sandia National Laboratories justifies using the 95th upper confidence limit of the mean chemical concentration for arsenic; methylene chloride; 1,1,2,2-tetrachloroethane; and trichloroethene to "recalculate" the incremental excess cancer risk, "because the site has been adequately characterized." (page 39). This

statement requires further explanation. A more detailed discussion of the how the mean concentrations were determined is required to determine whether this approach is acceptable and all these values should be reported in the risk assessment section in table format.

- ✓ For arsenic, how many samples were there? How many had positive detection values (presumably all of them)? What were the range, mean, and 95th confidence limits for the bore hole samples? How many samples were used to determine the background concentration of arsenic? What were the range, mean, and 95th confidence limits for the borehole samples which determined the background concentration?

- ✓ For 1,1,2,2-tetrachloroethane, it is stated that only 1 sample had a positive detection value. What is the detection limit and how high above the detection limit was that 1 positive sample? Does this mean that the mean concentration is equal to:

  {(95 samples x detection limit) + (1 sample x determined value)}/96

- ✓ For methylene chloride, only 9 samples had positive detection values, but all were estimated. What is the detection limit and what is the range of values for the 9 positive samples? Again, is the mean concentration equal to:

  {(87 samples x detection limit) + (9 sample x determined value)]/96}

- ✓ For trichloroethene, only 2 samples had positive detection values, but both were estimated. What is the detection limit and what are the values for the 2 positive samples? Again, is the mean concentration equal to:

  {(94 samples x detection limit) + (2 sample x determined value)]/96}

- Additional statistical analysis of the sampling data may reveal that the samples in which 1,1,2,2-tetrachloroethane and trichloroethene were detected can be considered outliers. In addition, given that 1,1,2,2-tetrachloroethane, methylene chloride, and trichloroethene are not chemicals listed on the MWL inventory, the uncertainty assessment could further discuss the likelihood of why these chemicals were detected and if these sampling data are meaningful.

- Sandia National Laboratories states that the inhalation pathway is driving the risk above the proposed standard for arsenic and trichloroethene and exposure via the inhalation pathway represents a conservative estimate (pages 39 & 40). The conclusion that negation of the inhalation pathway is reasonable is not supported by any data or discussion in this document. It is likely that the rationale for reaching this conclusion has been addressed in previous meetings and reports.

However, if this report is to serve as a final summary document of the risk assessment process, it would be very useful for 1-2 sentences to be included explaining why the inhalation pathway can be ignored.

- Since tritium is the one contaminant detected in soil sampling that clearly originated from the landfill, some additional explanation of the assumptions used for RESRAD would be useful, such as: for an industrial worker or for a resident how much soil is estimated to be ingested? How much inhalation occurs? It would also be useful to include a table that lists how much exposure (i.e. millirem/year (mrem/yr)) is estimated to occur from each of the exposure pathways (i.e. soil ingestion, inhalation, and plant uptake).

- Why is the dermal pathway for tritium considered insignificant?

- For all these routes of exposure was the highest detected tritium concentration used? If so, the Uncertainty Discussion (pages 38-40) should address this.

- A statement describing RESRAD would be useful. Such as "RESRAD (residual radioactive) is a computer model developed at Argonne National Laboratory for the U.S. Department of Energy to calculate site-specific radiation doses and cancer risk to chronically exposed on-site receptors."

- Why is the incremental TEDE (total effective dose equivalent) set at 15 mrem/yr for the industrial scenario and 75 mrem/yr for the residential scenario? What is the basis for this difference?

6.2 Summary of Evaluation of Ecological Risk Screening Assessment

The ecological risk screening assessment for the Mixed Waste Landfill at the Sandia National Laboratories is adequate and the general conclusion that ecological risks to radiological and non-radiological COPECs (constituents of potential ecological concern) appear to be low appears reasonable. This conclusion is based on the review of the *SWMU 76: Ecological Risk Screening Assessment* dated 05/01/01. Before embracing this conclusion, however, one significant issue requires further discussion and justification and a few minor items require clarification.

It should be noted that this ecological risk assessment is strictly based on the levels of contaminants that were detected in soil and groundwater sampling. The assessment did not consider risks posed by other chemicals that are present in the MWL, based on the inventory, that have not been released into the environment.

It also should be noted that the document reviewed is intended for an audience of regulators who have been involved in the risk assessment process for 4-5 years and are familiar with previous documents and meetings held prior to the release of this report.

Thus, as an outside scientific reviewer without knowledge of this previous process, there are minor items in this report that require clarification: (1) if this report is to serve as a final summary document of the risk assessment process for the outside public and scientific community, and (2) in order to fully understand the risk assessment process that led to the conclusion that the risk posed to ecological receptors is below that requiring action.

6.2.1 Significant Issue of Concern on the Ecological Risk Screening Assessment

- Sandia National Laboratories fails to apply an uncertainty factor when extrapolating the NOAEL (no observed adverse effect level) from the test species to the species of interest. This represents a significant limitation in estimating the risk potentially posed by COPECs to the ecological receptors. This may be less of a concern for extrapolation of NOAEL values determined in laboratory rats and mice to deer mice, but is of significant concern when extrapolating from mallards and ring doves to burrowing owls. There clearly will be differences in sensitivity among species and extrapolation must be applied in ecological risk assessment when effects for a valued species (burrowing owl in this case) must be estimated from data for a test species (mallard and ring doves) (Suter, 1993). The EPA "Risk Assessment Forum" recommended applying an uncertainty factor of 5 to account for differences in species sensitivity.

- It is understood that the standard procedure approved by New Mexico regulators and applied at the Sandia National Laboratories is to use body-scaling factors to adjust for differences in species sensitivity and not to apply uncertainty factors. The approach applied in this ecological risk assessment assumes that different species with similar body size will be equivalent in their toxicological sensitivity to a given chemical. Numerous studies in the scientific peer-reviewed literature do not support this assumption.

    - ✓ For example, the body size of lake trout and rainbow trout embryos are the same, but a body concentration of 75 part per trillion (ppt) of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, a persistent environmental pollutant, will kill the lake trout, while a body concentration of 500 ppt is needed to kill the rainbow trout (Walker et al., 1991; Walker and Peterson, 1991).

    - ✓ Similarly, mammals also exhibit dramatic species differences in their sensitivity to the same chemical even after body size is taken into account. An example of this is the responsiveness of different mammalian species to the limb teratogenicity of thalidomide. Even when body size is taken into account, only rabbits, humans, and non-human primates exhibit a significant teratogenic response to thalidomide exposure, while rats, cats, hamsters, and all but one mouse species do not (Addendum I, reviewed in Schardein 2000). And humans are more sensitive than any laboratory species tested.

- ✓ These are only two of numerous examples of species differences in toxicological sensitivity to chemicals demonstrated in the literature. Failure to adequately address potential differences in species sensitivity significantly limits the conclusions that can be made from the *SWMU 76: Ecological Risk Screening Assessment* dated 05/01/01.

6.2.2 Minor Issues Requiring Clarification on the Ecological Risk Screening Assessment

If this report is intended to serve as a final summary document of the risk assessment process for the outside public and scientific community, the following items require clarification or additional explanation.

- Sandia National Laboratories discuss a variety of approaches to decrease uncertainty associated with estimation of the true risk posed by the SWMU 76 to ecological receptors; however, the final hazard quotients and total hazard indices are never presented. In order for reviewers to evaluate the final conclusions of the report that ecological risks are predicted to be low, a final table must be included that documents the hazard quotients when using more realistic analyte concentrations and home range values and the final HI (hazard index) value for each ecological receptor. This is in contrast to the human health risk assessment where Sandia discusses its uncertainty assessment and then reports the new HQ (hazard quotient) values and cancer risk factors based on applying new uncertainty criteria. This should also be conducted for the ecological risk assessment.

- Page 46. VII.3.1.3 Ecological Receptors. It was never mentioned whether burrowing owls are resident at Kirtland Air Force Base. Given that the burrowing owl has been designated as a species of management concern by the U.S. Fish and Wildlife Service in Region 2, it would be nice to know if any censuses have been conducted and what the current status of burrowing owl population is on the Base. Given that the presence of small mammals at SWMU 76 was taken as a sign that COPECs are not having a significant impact on the small mammal population adjacent to the site, it would be useful to know the status of burrowing owl populations as well.

- Page 54. VII.3.5 Uncertainty Assessment. A thorough discussion of all the uncertainties associated with this risk assessment needs to be conducted in order to convince readers that the risk posed to ecological receptors is low. It is agreed that use of the maximum measured COPEC analyte concentrations and assumption of 2.6 acre SWMU 76 making up the entire home range of the burrowing owl represent conservative estimates for calculation of COPEC hazard quotients. These two assumptions will result in an overestimation of the potential risk. However, modeling the deer mouse as strictly herbivorous, omnivorous, or

50/50 mix represents the lowest-to-highest possible exposure scenarios and is not solely a conservative approach. However, it is not as obvious why the NOAEL would be considered a conservative measure. This should be discussed in greater detail.

- Table 21 Hazard Quotients for Ecological Receptors at SWMU 76. Add a footnote that illustrates how one hazard quotient is calculated or add a footnote that refers the readers to Appendix I (p. 69).

- Page 58, first paragraph, VII.3.5 Uncertainty Assessment. The data described in this paragraph would be easier to understand if it was also presented in a table. The table would include the analyte of interest, the detection limit, the modeled tissue concentration, and the actual measured tissue concentration if detected. How is this information integrated into calculating a revised HQ?

- Page 58, third paragraph, VII.3.5 Uncertainty Assessment. A more explanatory sentence regarding the home range size for the burrowing owl would be helpful. For example, . . . "Because SWMU 76 is approximately 2.6 acres, or 7.5% of a home range for a burrowing owl, an area use factor of 0.075 would be justified for this receptor."

6.3 Recommendations for Future Risk Assessments

- To provide adequate communication to the public, Sandia National Laboratories should provide an explanatory executive summary for the human health risk assessment and the environmental risk assessment documents. This information should describe the basic risk assessment processes that were used, the identified contaminants of concern, the uncertainties associated with them, and the basic conclusions reached from these processes. This information may already exist in the public information efforts previously conducted by Sandia, however, it is lacking from the risk assessment documents made available to the public.

- Sandia National Laboratories should conduct a human health and ecological risk assessment based on the landfill being excavated today, 5, and 20 years from today. This basic information would provide rationale to regulators and an explanation to the public why the landfill would be excavated at a later specified date rather than excavated today. The specific hazard indexes that would be associated with current excavation have not been quantified in documents available for review. These data would also be very useful for proposing alternatives to excavating today and estimating a future date at which time the landfill would be excavated.

Section 6.0 References

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Suter, G.W., II. 1993. Organism level effects. *In* Ecological Risk Assessment. Lewis Publishers, Chelsea, MI. pp. 175-246.

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U.S. Environmental Protection Agency. 1993. A review of ecological assessment case studies from a risk assessment perspective. EPA/630/R-92/005.

7.0 Analytical/Radiochemistry and Measurement Errors

Dr. Antonio Lara, Assistant Professor of Chemistry, New Mexico State University, reviewed analytical/radiochemistry and the potential measurement errors associated with the Sandia National Laboratories MWL. Other panel members contributed their findings in this area during the public meetings.

7.1 Summary

A key issue that arose in the review of MWL reports, sampling data, and outside reviews was an argument that the U-238/U-235 activity ratios were less than 21.76 in ground water samples and hence suggested non-natural or anthropogenic (man caused) sources of uranium existed beyond the MWL. Analytical results from two laboratories report mean values that are larger than the accepted natural abundance activity ratio of 21.76, and two other laboratories reported mean values that are less than the 21.76 values. However, the precision is extremely poor, and the isotopic activity ratio is not established. A recent round of analytical testing provides a method of measuring isotopic activity ratios using mass spectrometry and the precision is very tight. The method also strongly suggests that the uranium levels are those of the natural abundance of the element and thus it can be concluded that the MWL has not leached uranium into the groundwater. However, a different laboratory should confirm this finding using similar analytical methods to add an element of accuracy.

Trace measurements should be accompanied by the limit of detection (LOD) and the limit of quantitation (LOQ)**.** An evaluation is meaningful with this information. Data rejection should be done with a statistical basis. This means that there has to be a database. Continuous monitoring (if the MWL is left un-excavated) is essential to establish this database.

7.2 The U-238/U-235 Activity Ratio Issue

Dr. Mark Baskaran July 2000 report ("Mixed Waste Landfill Review") raised concerns about the possible release of radionuclides from the MWL that could be migrating to the groundwater and pose health problems. The major argument by the Baskaran report that groundwater contamination is possibly occurring and that the MWL is the source of these leaching nuclides is based on the measured radioactivity of U-238 and U-235. The accepted isotopic activity ratio, U-238/U-235, for the naturally occurring abundance of these two isotopes is 21.76. Numbers less than 21.76 indicate that there is an enhanced level of U-235, and this can only be possible if there is an anthropogenic source of uranium, such as from the MWL.

7.3 Validity of Uranium Measurements pre-2001

Between 1993 and 1995 four separate analytical laboratories reported uranium activity and U-238/U-235 activity ratios. The isotopic activity values were made by measuring the radioactivity of these isotopes, i.e., disintegration rates for the isotopes. The errors of measuring activity with this method can be substantial because the time required to count disintegrations can be long (10 seconds/disintegration/L for a reported U-235 measurement of 2.6 pCi/L and 3.7 minutes/disintegration/L for a U-238 measurement of 0.12 pCi/L). The uranium isotope activities, their associated errors (2-sigma values for 95% uncertainty), the U-238/U-235 activity ratios, and the uncertainty of the ratios calculated by propagation of error are tabulated in Table 3 and plotted in Figure 23. The interpretation by the Baskaran report was that the U-238/U-235 activity ratios were significantly less than 21.67 and therefore suggested possible leaching of uranium by the MWL to the groundwater. This interpretation, cannot be statistically justified for the following reasons:

- One laboratory, ITAS-OAK Ridge, has isotopic activity ratios that are significantly larger than 21.76 (mean activity ratio is 30.58). However, this laboratory does not report the associated error and it is therefore impossible to calculate the uncertainty of the activity ratio. An isotopic activity ratio that is larger than 21.76 is difficult to interpret, anyway.

- TMA Eberline laboratory also reports an isotopic activity ratio (mean activity ratio is 22.98) that is larger than 21.76. However, their precision is very poor; it is the poorest of the three reporting laboratories (see Figure 23). The range for the relative errors of the uranium isotopic activity ratios is 33-92% of the calculated ratio. This translates to absolute error margins that are 4.7 to 38.7 units above and below the reported isotopic activity ratio.

- The remaining two labs (Quanterra and LAS) have all of their values below the accepted 21.76 ratio (implications of altering the natural abundance in favor of U-235). However, again the precision is very poor, 35-95% relative error for Quanterra and 31-39% relative error for the LAS lab.

- For the three labs that report statistical errors (Figure 23), the measurements are indistinguishable from each other; i.e., because the uncertainty ranges are so large, the values between the labs are not significantly different. Except for two measurements, all the 2-sigma error bars overlap (95% uncertainty).

Some labs have isotopic activity ratios >21.76 and others have values <21.76. Yet all are statistically indistinguishable with 95% (2-sigma) error margins. The precision is poor. Thus, the assumption presented by the Baskaran report that uranium from the MWL might be affecting the groundwater, although not unreasonable, is questionable.

7.4 Validity of Uranium Measurements Made in the Year 2001

During the peer review process in March 2001, it was recommended by the peer panel that a more precise means of the isotope measurement could be performed with mass spectrometry. The errors associated with this method are smaller, especially as compared to the previous method of counting disintegrations. With this method, the abundance of the isotopes will limit the measurements, and with the concentration of uranium isotopes in the sample, the measurements would not be a problem and errors are much reduced compared to the earlier method. In April 2001 another round of sampling was performed using mass spectrometry.

The isotopic activity ratios and errors for the April 2001 samples are calculated in Table 4 and plotted in Figure 24. The relative propagation errors for the isotopic activity ratios range from 3-16% (the absolute error range was 0.7-3.5) with a 2-sigma error margin. Only three of the nine measurement do not include the accepted 21.76 value within the 2-sigma error margin. In addition, all the mass spectrometry values are very precise, and more importantly, the error bars all overlap. To emphasize the tremendous improvement in precision, this latest mass spectrometric method is also plotted (see Figure 25) to the same scale as Figure 23. This latest data set supports the theory that the uranium isotope ratio is the same as that for the natural abundance of the uranium isotopes and that the MWL is not leaching uranium into the groundwater.

The mass spectrometry method produces the most precise values, but one can beg the question – "are these activity ratios necessarily accurate?" The tight precision certainly favors this latest method over the previous method that incorporates nuclide disintegrations. However, mass spectrometry measurements by a different independent laboratory are needed to validate this conclusion. If their activity ratios are as precise and include the accepted 21.76 value, this would then confirm that uranium isotopes do reflect a natural abundance and the MWL is not leaching uranium into the groundwater.

It should be noted that this discussion is only valid if the error in discriminating between the isotopes for the "disintegration counting" method are negligible and the error of assigning disintegration rates for the individual isotopes in the mass spectrometry method are negligible.

7.5 Radionuclide Measurements and Minor Concerns

The uranium measurements can be analyzed in depth because some of the isotopes occur naturally and deviations from the natural concentration levels can be used to suggest that non-natural sources of uranium are possible. This comparison method is not possible with many of the other radioactive isotopes since they are man-made. However, if the mass spectrometry method proves accurate and precise for uranium analyses, then this method or a comparable method should be used for the other heavy elements in lieu of methods that count nuclide disintegrations. Of course, this would be the recommendation if the MWL is not excavated and monitoring procedures are established.

Methods that are valid for the heavy elements may not necessarily apply to the hydrogen isotopes, tritium for example. Hydrogen isotopes have established natural abundance ratios that can be used to calibrate the method. Important for these trace measurements are the limit of detection (LOD) and the limit of quantitation (LOQ). Reliable data will take into consideration signal to noise measurements and LODs are signals that are 3-sigma above the background and LOQs are signals that are 10-sigma above background.

7.6 Hazardous Wastes - Minor Concerns

Besides the radionuclides, there are hazardous chemicals buried in the MWL. Some of the chemicals that were detected may not originate from the MWL. Certainly, the detection of phthalic acid esters and other derivatives is a case where these compounds can be ignored as being leachates from the MWL. Phthalates occur in samples because they are ubiquitous. A statement to this effect is sufficient.

Organic compounds were also detected and they might be attributed to the monitoring well casings and packer apparatus and thus could be dismissed as leachates from the MWL. This supposition needs to be tested and reported. A suggestion would be to subject the drilling components and packer assembles to water and the conditions in the well. The solution would then be selectively tested for the specific compounds. If the selective compounds appear in this "blank", then leaching by the MWL can be disregarded for these compounds. To this end, the suspected packer assembly associated with the toluene detection will be removed in the summer/fall of 2001and replaced. Sandia National Laboratories is planning on performing tests to determine if this assembly is the source of the toluene.

7.7 Data Points that are Considered "Outliers" - Statistical Evaluation

There are a few cases where the presence of a compound or radionuclide in a sample is questionable or at least needs to be evaluated. The first concerns that should be addressed are the LOD and LOQ that were noted above. If the measurements are quantitative, then there are statistical tests to confirm, refute, or reject the existence of the "outlier" data. Even the simple Q-test could be applied. A statistical basis for data rejection should be used in every case that applies. As long as the MWL is not excavated, then continued monitoring is necessary to improve and augment the database. This becomes paramount for rejection criteria since they are based on statistical evaluations.

Figure 23: U-238/U-235 Activity Ratios (95% uncertainty error bars), 3 Analytical Labs

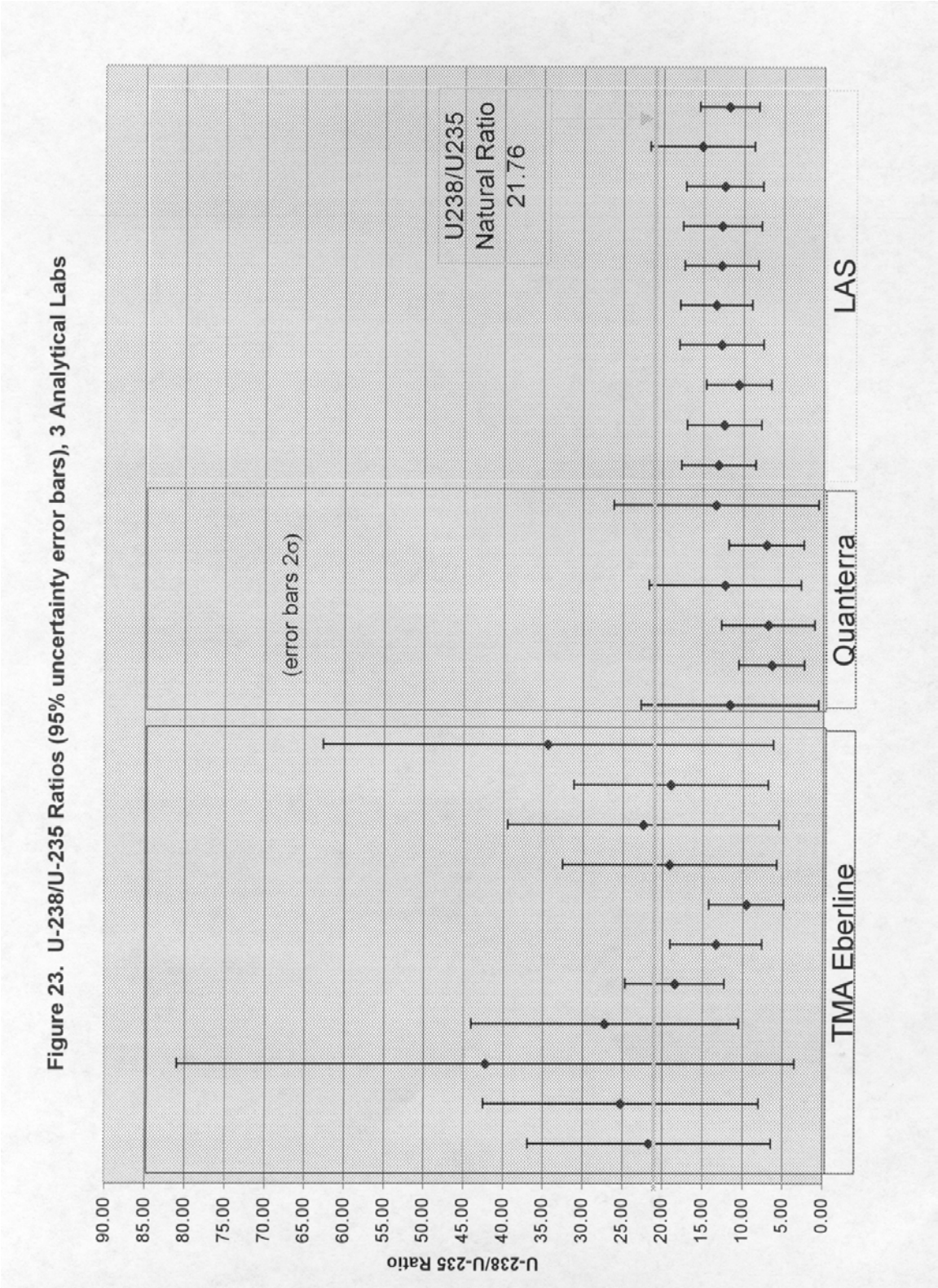

Figure 24: U-238/U-235 Activity Ratios (95% uncertainty error bars), ICP-MS Analyses

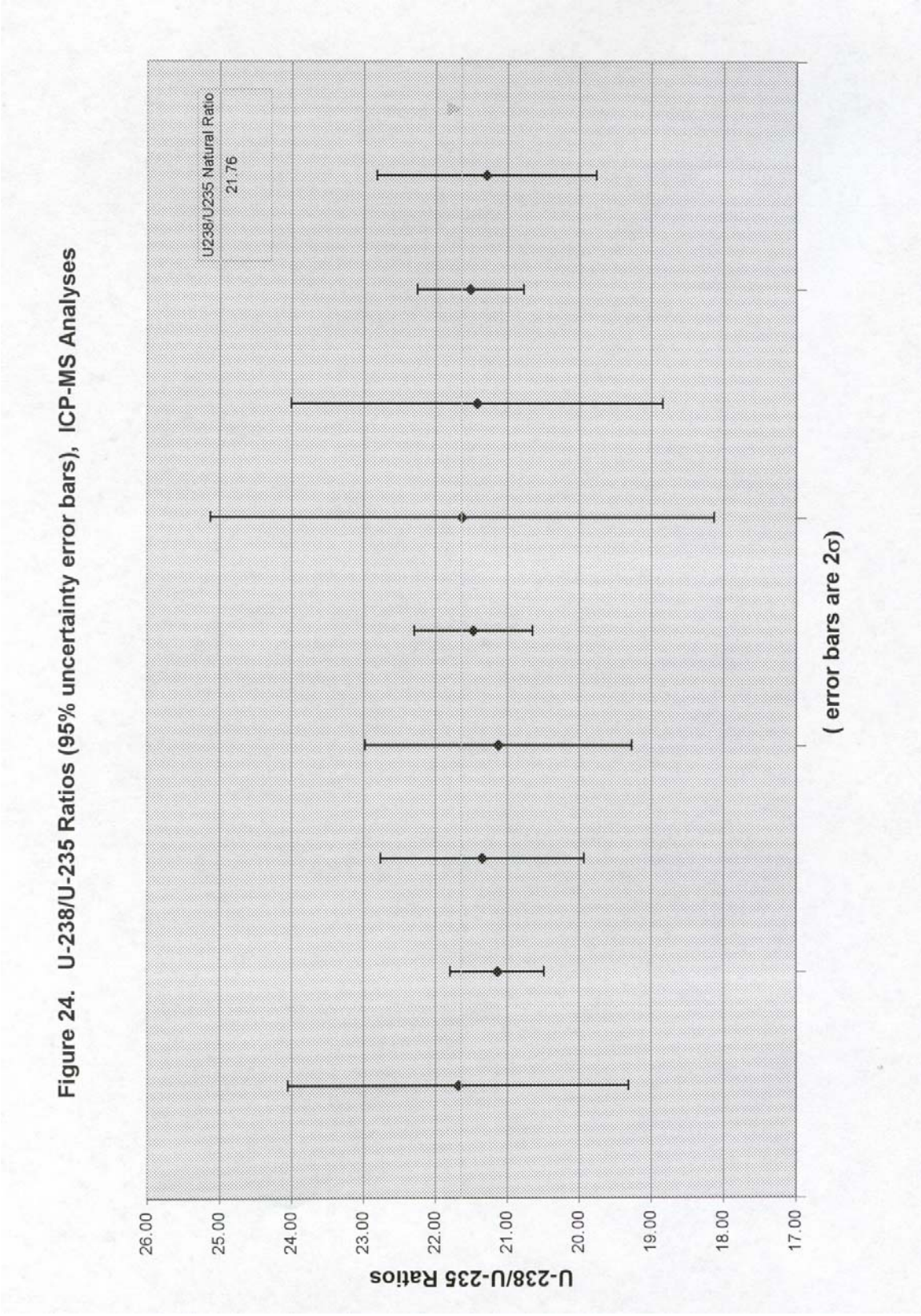

Figure 25: U-238/U-235 Activity Ratios (95% uncertainty error bars), ICP-MS Analyses [plotted at the same vertical scale as Figure 23]

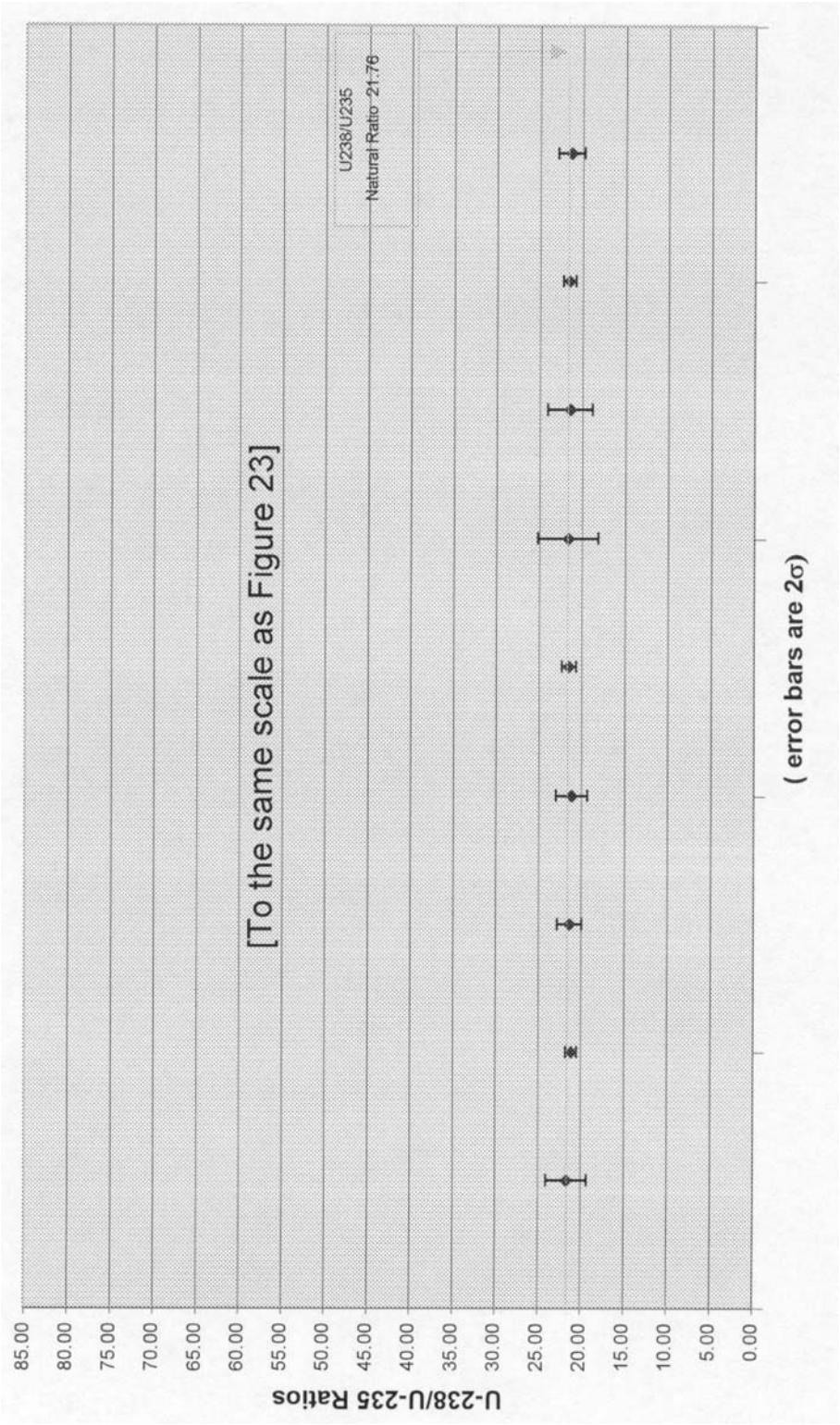

Table 3: Uranium Isotopic Activity Ratio Analysis/Monitoring Radioactive Disintegrations

Table 3. Uranium Isotopic Ratio Analyses / Monitoring Radioactive Disintegrations

Analytical lab	date	U-238 activity (pCi/L)	U-235 activity (pCi/L)	uncertainty U-238 (2σ)	uncertainty U-235 (2σ)	isotopic ratio 238/235	% rel uncertainty U-238	% rel uncertainty U-235	relative error of ratio	for plotting only	for plotting only	absolute error of ratio
TMA Eberline	8/11/93	2.6	0.12	0.44	0.082	21.67	16.9	68.3	70	TMA Eberline	21.67	15.3
	9/11/93	2.5	0.099	0.39	0.066	25.25	15.6	66.7	68	TMA Eberline	25.25	17.3
	10/11/93	3	0.071	0.5	0.064	42.25	16.7	90.1	92	TMA Eberline	42.25	38.7
	10/11/93	3	0.11	0.41	0.066	27.27	13.7	60.0	62	TMA Eberline	27.27	16.8
	11/11/93	2.4	0.13	0.21	0.042	18.46	8.8	32.3	33	TMA Eberline	18.46	6.2
	14/11/93	2.8	0.21	0.49	0.082	13.33	17.5	39.0	43	TMA Eberline	13.33	5.7
	2/5/94	2.2	0.23	0.49	0.1	9.57	22.3	43.5	49	TMA Eberline	9.57	4.7
	3/5/94	1.8	0.094	0.42	0.062	19.15	23.3	66.0	70	TMA Eberline	19.15	13.4
	3/5/94	2	0.089	0.46	0.064	22.47	23.0	71.9	75	TMA Eberline	22.47	17.0
	4/5/94	1.9	0.1	0.42	0.06	19.00	22.1	60.0	64	TMA Eberline	19.00	12.1
	31/5/94	2.1	0.061	0.48	0.048	34.43	22.9	78.7	82	TMA Eberline	34.43	28.2
Quanterra	24/10/94	2.33	0.2	0.7	0.18	11.65	30.0	90.0	95	Quanterra	11.65	11.1
	25/10/94	2.45	0.38	0.64	0.22	6.45	26.1	57.9	64	Quanterra	6.45	4.1
	25/10/94	2.2	0.32	0.71	0.25	6.88	32.3	78.1	85	Quanterra	6.88	5.8
	27/10/94	3.18	0.26	0.81	0.19	12.23	25.5	73.1	77	Quanterra	12.23	9.5
	27/10/94	3.05	0.43	0.8	0.26	7.09	26.2	60.5	66	Quanterra	7.09	4.7
	28/10/94	2.94	0.22	0.85	0.2	13.36	28.9	90.9	95	Quanterra	13.36	12.7
LAS	17/4/95	2.41	0.184	0.25	0.062	13.10	10.4	33.7	35	LAS	13.10	4.6
	17/4/95	2.02	0.163	0.22	0.058	12.39	10.9	35.6	37	LAS	12.39	4.6
	19/4/95	1.81	0.171	0.22	0.062	10.58	12.2	36.3	38	LAS	10.58	4.0
	19/4/95	1.81	0.142	0.21	0.056	12.75	11.6	39.4	41	LAS	12.75	5.2
	16/10/95	2.26	0.169	0.22	0.054	13.37	9.7	32.0	33	LAS	13.37	4.5
	16/10/95	1.86	0.146	0.2	0.05	12.74	10.8	34.2	36	LAS	12.74	4.6
	20/10/95	2.23	0.176	0.25	0.065	12.67	11.2	36.9	39	LAS	12.67	4.9
	20/10/95	1.72	0.139	0.2	0.051	12.37	11.6	36.7	38	LAS	12.37	4.8
	20/10/95	1.76	0.116	0.19	0.048	15.17	10.8	41.4	43	LAS	15.17	6.5
	23/10/95	2.21	0.187	0.22	0.055	11.82	10.0	29.4	31	LAS	11.82	3.7

Table 4: Uranium Isotopic Activity Ratio Analysis/ICP-Mass Spectrometry

Table 4. Uranium Isotopic Ratio Analyses / ICP - Mass Spectrometry

Analytical lab	date	U-238 activity (pCi/L)	U-235 activity (pCi/L)	uncertainty U-238 (2σ)	uncertainty U-235 (2σ)	isotopic ratio 238/235	% rel uncertainty U-238	% rel uncertainty U-235	relative error of ratio	for plotting only	for plotting only	absolute error of ratio
806 lab	5/4/01	1.431	0.066	0.087	0.006	21.68	6.1	9.1	11	1	21.68	2.4
rpsdp	9/4/01	1.67	0.079	0.047	0.001	21.14	2.8	1.3	3	2	21.14	0.7
	18/4/2001	2.028	0.095	0.118	0.003	21.35	5.8	3.2	7	3	21.35	1.4
	6/4/01	1.373	0.065	0.086	0.004	21.12	6.3	6.2	9	4	21.12	1.9
	4/4/01	1.546	0.072	0.041	0.002	21.47	2.7	2.8	4	5	21.47	0.8
	16/4/2001	2.444	0.113	0.278	0.013	21.63	11.4	11.5	16	6	21.63	3.5
	17/4/2001	2.207	0.103	0.183	0.009	21.43	8.3	8.7	12	7	21.43	2.6
	17/1/2001	3.249	0.151	0.091	0.003	21.52	2.8	2.0	3	8	21.52	0.7
	16/1/2001	2.853	0.134	0.114	0.008	21.29	4.0	6.0	7	9	21.29	1.5

8.0 Summary Findings and Recommendations

In its review of Sandia National Laboratories information and in its deliberations during March and May 2001 the peer panel identified that the information presented was consistently of high quality and the general approach taken to evaluate the performance of the MWL is valid with conclusions drawn being reasonable. The peer panel performed this evaluation of the MWL based on four factors:

- Fate and transport in all media;
- Short-term and long-term performance;
- Radioactive and hazardous waste/health physics; and
- Analytical/radiochemistry and measurement errors.

8.1 Summary of Fate and Transport of Contaminants

The data pertaining to fate and transport of tritium from the MWL presented and reviewed in this report (specifically, the spatial and temporal distribution of sampled tritium activities), appear to be consistent with those expected given the inventory, regional meteorology, subsurface soil conditions, and hydrologic parameters.

The modeling results, using GoldSim® to predict tritium concentrations in borehole soil water samples, show good agreement with the 1994-95 subsurface sampling data for the limited range of depth below the surface that the model was intended to simulate. Therefore, the assumptions made by Sandia National Laboratories appear to be valid and can be supported by independent modeling.

Future concentrations of tritium are not expected to increase but rather are expected to decrease over the next 10 years based on the natural decay of the tritium radionuclide.

8.2 Summary of Short-term and Long-term Performance

The MWL is unlined and has no engineered protection at this time from water intrusion. Although located within a secure federally operated site, the actual MWL is protected with a modest fence and very limited warning signs. The nature and amounts of wastes stored at the MWL site plus the location of the site next to a major growing metropolitan city represents a potential hazard to both humans and the environment. Based on the review of information on the MWL, however, the panel concluded that the landfill has neither resulted in human exposure to contaminants nor resulted in any significant environmental damage to date. Continuation of monitoring at the site will be essential to

determine if there is a potential for change in this status. If human exposure and/or environmental damage become imminent based on monitoring data, the hazardous/radioactive waste should ultimately be excavated and stored in a licensed repository. It is important to document the economic and environmental impacts associated with how best to excavate, when it is appropriate to excavate, and how to store the radioactive and hazardous waste from the MWL site if required at some future date.

8.3 Summary of Evaluation of Human Health and Ecological Risk Screening Assessments

It should be noted that the human health and ecological risk assessments are strictly based on the levels of contaminants that were detected in soil and groundwater sampling. The assessments did not consider risks posed by other chemicals that are present in the MWL, based on the inventory, that have not been released into the environment.

The human health risk screening assessment for the MWL at the Sandia National Laboratories is adequate and it would appear that the risk posed to human health from radiological and non-radiological contaminants of concern is below that requiring action. This conclusion is based on the review of the *SWMU 76: Risk Screening Assessment Report* dated 6/10/1999 and assumes that existing conditions remain.

The ecological risk screening assessment for the MWL at the Sandia National Laboratories is adequate and the general conclusion that ecological risks to radiological and non-radiological COPECs appear to be low appears reasonable. This conclusion is based on the review of the *SWMU 76: Ecological Risk Screening Assessment* dated 05/01/01 and assumes that existing conditions remain. Before embracing this conclusion, however, one significant issue requires further discussion. This issue is that Sandia National Laboratories fails to apply an uncertainty factor when extrapolating the NOAEL from the test species to the species of interest. This represents a significant limitation in estimating the risk potentially posed by COPECs to the ecological receptors.

To provide adequate communication to the public, Sandia National Laboratories should provide an explanatory executive summary for the human health risk assessment and the environmental risk assessment documents. This information should describe the basic risk assessment processes that were used, the identified contaminants of concern, the uncertainties associated with them, and the basic conclusions reached from these processes. This information may already exist in the public information efforts previously conducted by Sandia, however, it is lacking from the risk assessment documents made available to the public.

Sandia National Laboratories should conduct a human health and ecological risk assessment based on the landfill being excavated today, 5, and 20 years from today. This basic information would provide rationale to regulators and an explanation to the public why the landfill would be excavated at a later specified date rather than excavated today. The specific hazard indexes that would be associated with current excavation have not

been quantified in documents available for review. These data would also be very useful for proposing alternatives to excavating today and estimating a future date at which time the landfill would be excavated.

8.4 Summary of Analytical/Radiochemistry and Measurement Errors

A key issue that arose in the review of MWL reports, sampling data, and outside reviews was an argument that the U-238/U-235 activity ratios were less than 21.76 in ground water samples and hence suggested non-natural or anthropogenic sources of uranium existed beyond the MWL. Analytical results from two laboratories report mean values that are larger than the accepted natural abundance activity ratio of 21.76, and two other laboratories reported mean values that are less than the 21.76 values. However, the precision is extremely poor, and the activity ratio is not established. A recent round of analytical testing provides a method of measuring activity ratios using mass spectrometry and the precision is very tight. The method also strongly suggests that the uranium levels are those of the natural abundance of the element and thus it can be concluded that the MWL has not leached uranium into the groundwater. However, a different laboratory should confirm this finding using similar analytical methods to add an element of accuracy.

8.5 Additional Observations

It is recommended that Sandia National Laboratories should compile all of the relevant information related to this site in one document series. Much of this information is currently available in two public reading rooms in Albuquerque that are maintained by Sandia National Laboratories. The first is located at the University of New Mexico, Zimmerman Library, Government Information Department; and the second location is in an office building at 8338 B Comanche Road NE.

APPENDIX A

Biographic Sketches of

Peer Panel Members

and Facilitators

Appendix A
Biographic Sketches of Peer Panel Members and Facilitators

Peer Panel Members:

AIMONE-MARTIN, Catherine - Dr. Aimone-Martin received her BS degree in Geological Engineering from Michigan Tech and a Ph.D. from Northwestern University in Mineral Resources Engineering and Management and Civil (Geotechnical) Engineering. Dr. Aimone-Martin is a Professor Mineral Engineering at New Mexico Institute of Mining and Technology. Since 1971, she has worked in the mining industry and with geotechnical consulting firms in both the U.S. and Canada. Her research and training work spans 20 years with academia and national laboratories. Dr. Aimone-Martin's expertise is in the areas of soil mechanics and rock mechanics, explosives engineering and blasting vibration control, site investigation, drilling, instrumentation, engineering aspects of surface and groundwater, mine permitting and reclamation compliance, and geostatistics. Her experience includes the design and construction of mining and civil engineering projects such as solid waste landfills, earth dams and other hydrologic retention structures, slope stability analysis and assessment of earthquakes and blasting vibrations. Dr. Aimone-Martin has acted as Principal Engineer in the site investigation and permitting of three solid waste and one hazardous waste landfills in New Mexico. Since 1989, she has worked with both Sandia National Labs and Westinghouse WID on rock mechanics and performance assessment of the Waste Isolation Pilot Project (WIPP). Dr. Aimone-Martin serves on numerous committees and review panels for the National Research Council and the National Science Foundation, is a Board Member of the New Mexico Mining Association, and recently, appointed to the Surface Coal Mining Commission by New Mexico Governor Gary Johnson.

CAMPANA, Michael – Dr. Campana received his BS degree in Geology from the College of William and Mary, and an MS and a Ph.D. degree in Hydrology from the University of Arizona. He was at the Desert Research Institute from 1976-1989 and also taught in the University of Nevada's Hydrologic Sciences Program during this period. He is currently the Director, Water Resources Program and a Professor, Department of Earth and Planetary Sciences at the University of New Mexico. Dr. Campana has over twenty-five years experience in the academic field with responsibilities in geology, hydrogeology, earth and planetary sciences, and water resources. He is a Fulbright Scholar who taught watershed management at the University College of Belize and provided research assistance to Egyptian hydrologists and engineers. Over the past twelve years, Dr. Campana has performed research in hydrogeology for the U.S. Geological Survey, State of New Mexico, U.S. Department of Energy, Sandia National Laboratories, and the National Science Foundation and has over 50 publications. He is a member of the National Research Council's Committee on USGS Water Resources Research; and holds board positions with the Association of Ground-Water Scientists and Engineers, Universities Council on Water Resources, and the American Institute of Hydrology.

LARA, Antonio – Dr. Lara received his BS degree in Math Education and a MS degree in Organic Chemistry from New Mexico State University. After receiving these degrees, he taught science courses at Gadsden High School for eight years and was named the 1982 Outstanding Science Teacher in New Mexico, by the New Mexico State Academy of Science. In 1990, Dr Lara received his Ph.D. degree in Analytical Chemistry. He is currently an Assistant Professor of Chemistry at New Mexico State University and has been teaching at the University for the past twelve years. Dr. Lara specializes in soil chemistry, specifically modified clays. He has authored numerous papers on clay properties for industrial use. Research currently underway for the U.S. Department of Energy is the use of specialized clays as air scrubbers for Mexican brick kilns along the border with the United States.

NUTTALL, Eric - Dr. Nuttall received his BS degree in Chemical Engineering from the University of Utah and an MS and a Ph.D. degree Chemical Engineering with a Minor Nuclear Engineering, from the University of Arizona. He is currently a Professor of Chemical/Nuclear Engineering at the University of New Mexico where he has served since 1974. Prior to coming to UNM, he was a senior research engineer at Garrett Research and Development Co. a subsidiary of Occidental Petroleum Company. Dr. Nuttall serves on the ITRC (a national committee composed of state regulators and stakeholders) and is listed in Who's Who in Engineering, the International Who's Who in Education and Who's Who in the West. He teaches bioremediation and has numerous publications in this area. He is currently co-authoring a book on this topic with Professor Werner Lutze. He is also a co-founder and developer of the UNM Center for Radioactive Waste Management. Dr. Nuttall has consulted for many years both Los Alamos and Sandia National Laboratories in the area of nuclear waste manage. His research includes fate and transport studies of radioactive waste. He has consulted with the laboratories in the area of high-level radioactive waste disposal including the Seabed disposal project and the Yucca Mountain project. Currently he is developing in-situ bioremediation processes for the treatment of groundwater.

WALKER, Mary - Dr. Walker received her BS degrees in Wildlife Ecology and Journalism, and Ph.D. degree in Environmental Toxicology from the University of Wisconsin-Madison. She joined the faculty at the College of Pharmacy at the University of New Mexico in 1997 where she teaches both Pharmacy professional students and Toxicology graduate students. She maintains a $1.5 million research laboratory studying birth defects induced by dioxin and polychlorinated biphenyls with funding from the National Institutes of Environmental Health Sciences and the American Heart Association. Prior to joining UNM, she worked with U.S. Fish and Wildlife Service and collaborated on projects with the U.S. Environmental Protection Agency to predict the risk that dioxins and related chemicals posed to fish and wildlife around the Great Lakes. She has also served as a toxicology consultant to the Great Lakes Fisheries Commission, the Wisconsin Department of Natural Resources, and the International Joint Commission, a subagency of the U.S. State Department. She currently serves as the Vice President of the Mountain West Chapter of the Society of Toxicology and has previously served on the Editorial Board for the Society of Environmental Toxicology and Chemistry. She has

authored numerous peer-reviewed publications and has made presentations in the area of developmental and environmental toxicology.

Peer Panel Facilitators:

BHADA, Rohinton (Ron) - Dr. Bhada received his BS, MS and Ph.D. degrees in Chemical Engineering from the University of Michigan and earned an MBA in Management from the University of Akron. He joined New Mexico State University as Department Head of Chemical Engineering in 1988, retired in 1999; and is currently Emeritus Associate Dean of Engineering, Chemical Engineering Head, and Executive Director of WERC (a Consortium for Environmental Education & Technology Development). Prior to joining NMSU, Dr Bhada was employed for 29 years at Babcock and Wilcox Company, a major energy systems company actively engaged in environmental management. At Babcox and Wilcox, Dr. Bhada was involved in activities ranging from applied research to field demonstrations in environmental control, waste stream chemical recovery, coal gasification, advanced power generation, fluidized bed combustion, and refuse incineration. He has over 80 publications and papers, has published over 100 reports on original research, and holds a U.S. Patent on chemical recovery from a waste stream. He is a registered professional engineer, Diplomat of the American Association of Environmental Engineers, a Councilor of the Oak Ridge Associated Universities, and a member of the National Research Committee of the American Institute of Chemical Engineers.

CARLSON, Timothy - Mr. Carlson received his BS in Civil Engineering and MS in Environmental Engineering at Arizona State University and is a registered Professional Engineer in Colorado. He has more than thirty years experience in the environmental cleanup arena working in the private sector with various states, EPA regions, and Federal agencies (DOE, DOD, Corps of Engineers, and the National Park Service). He is currently the President of Sensible Environmental Solutions, a small non-profit environmental research corporation. Mr. Carlson's projects have included the planning, design, construction management, and operation assistance for numerous waste treatment systems under the regulatory authority of the Clean Water Act and CERCLA. As a Principal Scientist for RUST Geotech Inc. at the Grand Junction Projects Office, work on DOE projects has included several CERCLA actions that have lead to Records of Decisions; DOE Headquarters support on the identification of needs for the Environmental Restoration Program and the relationship of technology efforts to meeting those needs; and the development and coordination of a comprehensive implementation program for several innovative treatment technologies. He is principally known for his abilities to gain acceptance by the public and regulatory agencies of difficult and controversial projects from planning and design through construction. These projects often times involved innovative approaches that required the acceptance by a public with diverse priorities and agendas. Several of these projects, received not only local acclaim, but also regional and national recognition for environmental engineering excellence. Another aspect of Mr. Carlson's capabilities has been the organization and performance of high level peer reviews of environmental technologies. These included an overall

assessment of existing technologies for DOE's radioactive and mixed waste problems, molten salt oxidation for the treatment of organic wastes, a proprietary Russian technology for the separation of cesium and strontium from high-level wastes, and engineering barriers for DOE's Waste Isolation Pilot Plant. Mr. Carlson has participated on two peer panels which evaluated the technology options for treating mixed waste at Los Alamos National Laboratory and at the Savannah River Site.

WERC Staff:

GHASSEMI, Abbas - Dr. Ghassemi received his BS from the University of Oklahoma and his MS and Ph.D. in Chemical Engineering from New Mexico State University in Las Cruces, NM. He has more than 20 years of industrial, academic, chemical, and environmental hands-on engineering experience. Dr. Ghassemi is an Associate Professor Chemical Engineering and is the Executive Director of WERC (a Consortium for Environmental Education & Technology Development). Over the past 10 years, Dr. Ghassemi has been responsible for managing the following WERC programs: Industrial Affiliates, Summer Environmental Design Institute, International Environmental Design Contest, outreach, technology transfer and demonstration, new business development and new technology development programs. Prior to joining NMSU, Dr. Ghassemi compiled extensive experience in technical and marketing management, process control, process operation and optimization by more than ten years of employment at Fisher Controls International and Monsanto Company. He has extensive experience in the environmental field including pollution prevention, waste management, environmental remediation, and technology identification. He has served as technical expert in several environmental litigation cases as well as technical peer review panels and international training projects in the environmental health and risk assessment fields. He is the author of more than 75 papers and publications in the fields of process control, thermodynamics, environmental engineering and education. He is also co-editor and contributor to several textbooks in the area of environmental technology and management.

APPENDIX B

Sandia National Laboratories

Mixed Waste Landfill

Inventory of Disposed Materials by Pit and Trench

Appendix B
Sandia National Laboratories
Mixed Waste Landfill
Inventory of Disposed Materials by Pit and Trench

The following inventory by pit and trench was compiled from classified and unclassified disposal records, interviews with current and retired employees, solid waste information sheets, and nuclear material management records. Considerable effort was made to maintain consistency in nomenclature and units. Commonly used acronyms are as follows:
1) MFP – multiple fission products: the nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the fission fragment's radioactive decay.
2) DU – depleted uranium
3) activation – the process of making a material radioactive by bombardment with neutron, protons or other nuclear radiation.
4) induced activity – radioactivity that is created when stable substances are bombarded by neutron e.g., the stable isotope Co-59 becomes the radioactive isotope Co-60 under neutron bombardment.

TRENCH A

Differential amplifiers; thermocouples; compressors; MFP- and tritium-contaminated fume hoods, ducting, motors, fans, and plenums; TV cameras, tripods, and telemetry components; MFP-contaminated cooling systems, coils, surge tanks (5 ft diameter X 11 ft long), piping, pumps, couplings, and valves; experimental stainless steel canisters; 17 each 55-gallon drums containing MFP-contaminated demineralizer resin; 2 each 55-gallon drums of MFP-contaminated concrete; empty oxygen cylinders; boxes of fluorescent light bulbs; roll-up door and associated equipment from a TA-5 "KIVA;" shield door from reactor pit; voltage-controlled oscillators, calibrators, and gyros; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; tritium luminary dials; military radium altimeters and gauges; Ni-63 tube; parachute; Sr-90 nuclear cells; flash heating equipment and associated parts; MFP-contaminated L-shaped aluminum chassis; DU in graphite matrix; stainless steel ducting; 61 each spark gap tubes (100 mrem/hr on contact); aluminum sleeve with lead ballast; tritium beds and valves; shock jigs with tubes; 31 each 0.5 Ci Kr-85 tubes and cells; one each 20 ft long X 2 ft diameter heat exchanger, coolant pumps, piping, and valving; air conditioners; tritium targets (10 Ci each) and tubes (100 mCi each); wooden ladder; MFP-, DU-, and tritium-contaminated vacuum cleaners; vacuum pumps and skids; stainless steel sample tubes; irradiated metal samples (5 rem/hr on contact); ion generators; 5-gallons of oil absorbed on vermiculite in sealed A/N can; 128 ft^2 of sheet metal; skid loaded with 300 lbs. of paraffin; 12 each skids of MFP-contaminated concrete blocks, MFP-contaminated lead bricks; 2,600 kg DU.

943 ft^3 of TA-5 routine operational and miscellaneous decontamination waste.

TRENCH B

HEPA filters, fiberglass filters, final and prefilters; MFP-, DU-, and tritium-contaminated vacuum cleaners; cables; ultra-sonic air samplers; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; MFP- and tritium-contaminated fume hoods, ducting, motors, fans, and plenums; boxes of fluorescent light bulbs; sanding disks; neutron generator tubes; backing plates from TA-5 experimental apparatus; packing materials and wooden shipping crates; metal drums from NTS containing DU; alpha-contaminated gas bottles; empty liquid scintillation vials; Ta-182 contaminated platinum-tungsten scrap; heater elements; 10 Ci tritium targets; neutron generator magnets; 14 each empty steel gas cylinders contaminated with DU; 9 each MFP-contaminated ceramic tubes; 1.5-gallons of solvents absorbed on vermiculite in sealed A/N cans; 6 each small storage cabinets; vacuum system components including water circulators, valves, diffusion pumps, fittings, gas analyzers, and vacuum pumps; gas sample bottles from NTS; tritium-contaminated tools; DU metal shavings and cuttings; Victoreen Sr-90 ion chambers; glove box and work bench; demineralizer vessel from reactor; neutron radiograph equipment; thermal reflecting rings; micro scales; Kr-85 light sources; 11 kg deuterium containing 0.25 Ci of tritium; 1-gallon toluene absorbed on vermiculite in sealed A/N can; static meter; Ta-182 pellets; demineralization and radiography tubes.

1326 ft^3 of TA-5 routine operational and miscellaneous decontamination waste.

TRENCH C

Nuclear fuel shipping cask cleanup debris; tritium and C-14 labeled amino acids and tritium labeled uridine; scrap metal contaminated with DU from burn test; 7.1 Ci tritium pellets; uranyl nitrate; “dining car” test hardware; MFP-, DU-, and tritium-contaminated vacuum cleaners; vacuum hose contaminated during cleaning of thorium cloth and thorium cloth debris; concrete crucibles used in reactor safety studies; Kr-85 particle size analyzer; 1,000 lead bricks contaminated with tritium and Na-22; 43 MFP-contaminated lead bricks; 73 each integrated circuits; Ba-133 reactor bolts; flexible glove box ducting; 2 each mechanical vacuum pumps; Sr-90 contaminated carpet; Cs-137 spark gaps; Na-22 cleanup materials, source holders, and shield (1.5 rem/hr on contact); DU-contaminated waste containers; tritium-contaminated vacuum system and power supply; DU billet, hemisphere, and sphere; Pu-238 contaminated hood exhaust hose; Co-60 debris from trailer used to support nuclear fuel shipping cask; MFP-contaminated hot exhaust system prefilters, HEPA filters, and absolute pressure filters; containerized DU residue, turnings, metal workings, and cuttings; surge voltage arrester; tritium-contaminated pump; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; wooden shipping crates; 13 each Po-210 contaminated static eliminators; one each 62 mCi Se-75 source and one each 1.0 mCi Ta-182

source in sealed A/N can; tritium-contaminated fume hood and exhaust plenum; 2.0 kg deuterium absorbed on vermiculite in sealed A/N can; 12 each 55-gallon drums of MFP-contaminated spent demineralizer resin; DU-contaminated lucite table; 4 each TV cameras; tritium-contaminated ion pump; 1-gallon tritium-contaminated acetone solidified with Safe-T-Set; 24 kg lithium-6 fluoride; 4 each irradiated high speed cameras, lenses, and one telescope; one each 0.1 mCi Ra-226/Be source encapsulated in concrete-filled A/N can; 2 each DU-contaminated glove boxes; 32.1 Ci tritium; 377 kg DU.

Trace Eu-152, Ba-133, I-129, Na-22, Sr-90, Ni-63, Tc-99, Gd-153, Ag-110m, Pm-147, Sr-85, Sb-125, Ta-182, Ge-68, Mn-54, and Fe-55.

1,159 ft^3 of TA-5 routine operational and miscellaneous decontamination waste.

TRENCH D

Compensator and cables from TA-1; tritium-contaminated water and erbium tritide powder; DU-contaminated rocket motors; broken Ra-226 source in plastic holder; corroded and broken 6-ft aluminum step ladder; 13 each 55-gallon drums containing MFP-contaminated spent demineralizer resin; DU residue, turnings, metal workings, and cuttings; MFP-contaminated tape recorders, transmitters, and video cameras; MFP-contaminated compensated ion chamber; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; 4 each aluminum “KIVA” doors from reactor; PEG housing and lid from NTS; MFP-contaminated fuel holsters; ultra filters and ultra filter plenums; MFP-contaminated hot exhaust system prefilters, absolute pressure filters, and plenums; HEPA filters; MFP-contaminated conduit and sheet metal; 2 each sealed Cr-57 sources; TA-1 bldg. 802 construction materials and scrap; MFP-, DU-, and tritium-contaminated vacuum cleaners; TA-5 liquid waste disposal system drain pipes; “Cypress” packaging material from NTS; “Ming Vaso” rad test debris from NTS; “Snap 27” test debris; “Hudson Moon” cleanup and packaging materials from NTS; “Mint Leaf” packaging and cleanup materials from NTS; “Diana Mist” packaging and cleanup materials from NTS; “Thoria” cleanup and packaging materials from NTS; old “KIVA” floor including sheet-rock, wood, and miscellaneous waste from installation of new “KIVA” floor; MFP-contaminated spent demineralizer columns and cartridges; thoria crucibles and tubing; old reactor boiler with associated radiators, piping, and valves; activated reactor stainless steel support tower, cryostat tube and head; empty thorium impact capsules; empty wooden shipping crates for fuel elements; tritium-contaminated power supply, balance, volt meter, ammeter, bridge, vacuum pump, microscope mount, plug-in units, and glass tubes; neutron radiography tube and beam catcher; ultra-sonic bath and power unit; obsolete Bell Labs experimental core tube (10 rem/hr on contact).

2,315 ft^3 of TA-5 routine operational and miscellaneous decontamination waste.

TRENCH E

38 each 55-gallon drums of MFP-contaminated spent demineralizer resin; 7 each 55-gallon drums from Three Mile Island containing MFP-contaminated cables, instruments, and electronic components; 11 each Po-210 contaminated static eliminators; 10-gallons Cs-137 solution solidified with Safe-T-Set in sealed A/N can; oil from lapidary shop solidified with soil in sealed A/N can; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; 6 each irradiated 9 ft 10 in. long X 9 in. dia. stainless steel storage tubes and holding rings; activated top and bottom reactor vessel sections; hydraulic pumps; ion pumps; steel frame and motor assembly from "KIVA" door; burned wood from weapons experiment; 2 each burned empty 55-gallon drums; MFP-contaminated vacuum pumps; obsolete and old test equipment and materials used in reactor fuel tests; DU-contaminated glove box; HEPA filters from hot exhaust plenum; DU-contaminated vacuum and filtering system bracket and assembly; DU-contaminated machine shop cabinets, work tables, filters, and ground cloths; 4 each TV cameras; 45 Ci neutron generator tubes; DU-contaminated crucibles; janitorial barrels; vacuum pumps; file cabinets; 70 lbs. thoria-contaminated soil; tritium-contaminated ion pump; one damaged DU-contaminated shake table or "vibrator" for sieving powdered DU; 10,000 lbs. of decommissioned reactor debris from extensive modifications to the reactor including ventilation ducts, conduit, PVC, nuts and bolts, hot water radiators, metal support parts, concrete, insulation, cable, air blowers, camera equipment, light bulbs, metal stands, electronic equipment, vacuum cleaners, pumps, coveralls, lumber, scaffolding, tables, chairs, gauges, regulators, valves, glove boxes, and stainless steel; 2,500 ft^3 of DU-contaminated soil; plywood ventilation duct; Mettler balance; Sartorius balance; fume hood; Magniwhirl bath; lab furnace; obsolete fire alarm system and associated electrical equipment; scrap wire; 11 each 55-gallon drums numbered 1 through 11: drums 1 through 3 contain 18 nanocuries/gram alpha emitters, drums 4 through 11 contain 8 nanocuries/gram alpha emitters; 2 kg thorium; 8 kg DU; 122 Ci tritium.

Trace amounts of Ce-144, K-40, Zr-95, Nb-95, Sr-85, Eu-152, Eu-155, Ni-63, and Po-210.

Radioactive waste from the Inhalation Toxicology Research Institute (ITRI): ITRI typically disposed of their radioactive waste at the commercial radioactive waste disposal site in Beatty, Nevada. The state of Nevada closed this radioactive disposal site in 1979. SNL, NM accepted a shipment of 119 each 55-gallon drums and 13 plywood boxes of radioactive waste from ITRI in October 1979. A copy of the ITRI radioactive shipment record dated 4/28/80 is attached.

1,093 ft^3 of routine operational waste and miscellaneous decontamination waste.

TRENCH F

Tritium and DU-contaminated glove boxes; ducting; stainless steel; 6 each 55-gallon poly drums containing MFP-contaminated spent demineralizer resin; wooden shipping crates; steel cladding

and zirconium insulation; dilute nitric acid neutralized with $CaCO_3$, Na_2CO_3, and $NaHCO_3$ and solidified with yellow powder material; Electro-glo electropolishing agent solution with concentrated phosphoric acid neutralized with Na_2CO_3 and NaOH and solidified with yellow powder material; lab benches; metal table; two each glove boxes; HEPA and prefilters.

There are 5 spent, nuclear fuel-shipping casks of various sizes in Trench F. They include the Hallam cask, the Helicopter cask, the IF-100 cask, the IF-200 cask, and the Yankee cask. These casks were subject to various destructive tests in the mid-1970's to meet Nuclear Waste Policy Act certification requirements for shipping spent nuclear fuel assemblies. These casks, soon to be retired, were removed from active service for destructive testing. The casks were equipped with fuel mock-ups for destructive testing.

The Nuclear Power Facility provided the Hallum cask to Sandia National Laboratories for torch fire tests. The Hallum cask is 19 ft long x 3 ft in diameter and weighs 40 tons. The cask consists of two stainless steel cylinders separated by 8.5 inches of lead shielding in the annulus.

Pratt and Whitney provided the Helicopter cask for drop tests from 2,000 ft above ground surface. The Helicopter cask is a pot-type cask weighing 3 tons. The interior cavity is 4 inches in diameter and 17.5 inches high surrounded by 10 inches of lead.

The Yankee cask and its Atlas railcar were provided by Westinghouse for sled-track impact tests. The Yankee cask is 13 ft long x 5 ft in diameter and weighs 37 tons. The cask consists of two stainless steel cylinders separated by 8.5 inches of lead shielding in the annulus.

The IF-100 and IF-200 casks were provided by General Electric for sled-track impact tests. The IF-100 cask is 13 ft long x 32 inches in diameter and weighs 22 tons. The cask consists of two stainless steel cylinders separated by 8.5 inches of lead shielding in the annulus. The IF-200 cask is 13 ft long x 3 ft in diameter weighing 25 tons. The cask consists of two stainless steel cylinders separated by 8.5 inches of lead shielding in the annulus.

A semi-tractor trailer or "carriage" used for transporting spent, nuclear fuel shipping casks is buried in Trench F. The trailer was contaminated with Cs-137. The trailer was contaminated by a leaking shipping cask that contained a spent, nuclear fuel assembly destined for TA-5. The cask that contained the spent, fuel assembly leaked water during shipment. The cask was decontaminated and returned to Savannah River via another trailer, however, the contaminated trailer was designated non-recoverable and buried. A picture of the trailer buried in Trench F is attached.

792 ft^3 of routine operational and miscellaneous decontamination waste.

TRENCH G

Trench G was the last operational disposal trench. It contained very little waste, as indicated by the geophysics in the MWL Phase 2 RFI Report, when the MWL was closed in December 1988.

Thorium and uranium alloyed aluminum Polaris missile sections; 3 each glove boxes; one Mettler balance and fume hood contaminated with fission products; MFP-contaminated concrete; 2 each 55-gallon poly drums containing MFP-contaminated spent demineralizer resin; fluorescent light bulbs; HEPA and prefilters; MFP-contaminated TV camera; 1,000 cubic yards of dirt from the reactor berm removal.

581 ft^3 of routine operational wastes and miscellaneous decontamination waste.

PIT SP-1

Two each depleted tritium beds; 3-gallons NaOH; 3-gallons acid waste; 1 poly bottle uranium solution; out-dated standard solutions; 30-gallons tritium water; miscellaneous chemicals with beta/gamma contamination; 4 kg enriched lithium; 4 kg Li-6; 408 grams U-235.

PIT SP-2

A plutonium arc tunnel is buried in SP-2. The plutonium arc tunnel was used to simulate ballistic missile re-entry into the earth's atmosphere. Pu-238 microspheres, ranging from 2 to 20 micrometers in diameter, were injected into the arc tunnel under the influence of plasma to determine temperature and pressure effects on nuclear weapon components. The apparatus is 4 ft x 4 ft x 10 ft long with a 2 ft x 2 ft x 5 ft central section. Glove boxes are attached at each end. Approximately 20 microspheres remained in the tunnel when it was buried in 1968.

PIT SP-3

A beryllium catcher is buried in SP-3. The Be-catcher was used to "catch" projectiles fired from various guns and howitzers. Experimental projectiles containing Be and DU were retrieved and studied in tests. The BE-catcher contained fine particles of Be and DU when buried in 1968.

PIT SP-4

Nuclear reactor vessel plates from a decommissioned nuclear reactor are buried in SP-4. The vessel plates came from a nuclear reactor in the San Fernando Valley. The reactor, when decommissioned in 1978, was cut to pieces and shipped to Beatty, Nevada for disposal. Six-foot sections of the outer vessel were salvaged and shipped to Sandia for fission product and Co-60 activation studies. The sections were stored in SP-4 and never tested and remain there to this

day. The vessel plates, at the time of burial, measured 2 rem/hour on contact. SP-4 is lined with concrete culvert and concrete bottom-cap making it the only lined pit at the MWL.

PIT SP-5

A 10,000 Ci Co-60 source is buried in SP-5. The 10,000 Ci Co-60 source was manufactured by Oak Ridge National Laboratories in 1960 and delivered to Sandia National Laboratories for deployment in the gamma irradiation facility. The source consists of 12 stainless steel rods, 12 inches long x 0.5 inches in diameter, each containing 8 cobalt metal pellets. Each cobalt pellet is 0.5 inches long. The cobalt metal pellets are located in the center of each rod with 4 inches of lead as shielding filling each end. Each cobalt rod contained approximately 840 Ci in September 1961. The Co-60 source was removed from service and transferred to SP-5 in June 1987. The Co-60 source was buried in a 6.7 ft^3 lead burial cask, which was in turn encased in a 24 yd^3 concrete burial cask. The original 10,000 Ci source will have decayed to 76 Ci as of September 1998, or 6.4 Ci per rod.

PIT 1

DU-contaminated weapons components; mass of DU unknown.

PIT 2

DU-contaminated debris bed; DU-contaminated weapons components; mass of DU unknown.

PIT 3A

DU-contaminated weapons components; 22 kg DU.

PIT 3B

DU-contaminated Mark III missile sections; mass of DU unknown.

PIT 4

DU-contaminated weapons components; mass of DU unknown.

PIT 5

DU-contaminated weapons components; mass of DU unknown.

PIT 6

DU-contaminated weapons components; mass of DU unknown.

PIT 7

DU-contaminated weapons components; 846 kg DU.

PIT 8

DU-contaminated weapons components; mass of DU unknown.

PIT 9

DU-contaminated weapons components; mass of DU unknown.

PIT 10

DU-contaminated weapons components; 178 kg DU.

PIT 11

7 NTS test shapes; 42 kg DU.

PIT 12

Neutron generator tubes; 1 kg thorium; 103 kg DU.

PIT 13

One each 1,800 Ci Co-60 source sealed in a lead and steel burial cask encapsulated in two truckloads of concrete; one each 98 microCi Ra-226 source, one each 1.3 microCi Ra-226 source, two each 5.0 microCi Ra-226 sources, and one each 1.0 microCi Ra-226 source encapsulated in concrete-filled A/N can.

PIT 14

One each sealed 5.0 microCi Po-210 source and source holder; one each sealed 1.0 microCi Po-210 source; miscellaneous uranium and beryllium waste; “Cypress” test debris from NTS; DU-contaminated vacuum cleaner; 3 Ci tritium water; 100 mCi tritium oxide; Pu-238, Po-210, and tritium-contaminated miscellaneous operational and lab waste; tritium-contaminated pumps and

valves; Pu-238 contaminated air sampler; neutron generator tubes; a large weapon shell (18 megaton WWII vintage); DU-contaminated weapons components; 178 kg DU.

PIT 15

One each 102.1 microCi Ra-226/Be source and one each 5.5 microCi source in a encapsulated in concrete-filled 55-gallon drum; fume hood filters and filter housings; reactor fuel element ends (5 rem/hr on contact); "Cypress" test debris from NTS; neutron generator tubes and targets; DU-contaminated weapons components; Pershing missile debris; 167 kg DU; 49 grams U-235; 30 Ci tritium.

PIT 16

One each sealed 2.5 Ci Co-60 source encapsulated in a concrete-filled lead cask; two each non-functional 1.5 mCi Ra-226 ionization alphatron gauges encapsulated in a concrete-filled A/N can; nine each Ba-133 reactor bolts; 2 each 52 Ci Co-60 pencils encapsulated in a lead-lined concrete-filled 55-gallon drum; 2 each 10.0 microCi Ra-226/Be sources in lead container encapsulated in a concrete-filled 5-gallon A/N can; one each 1,000 Ci Co-60 source encapsulated in a lead-lined, concrete-filled 55-gallon drum; ionization chambers and current regulators; one each 0.8 mCi Kr-85 source encapsulated in a concrete-filled A/N can; one each 40 mCi Am-241 source encapsulated in a concrete-filled A/N can; one each 18.9 Ci Kr-85 nuclear battery in a steel tube encapsulated in concrete-filled A/N can; SER control rod guides encapsulated in a lead-lined, concrete-filled A/N can (50 rem/hr on contact); thorium metal scrap; one each Sb-124 source projectile (10 rem/hr on contact); 20 each 5.0 microCi Ra-226/Be sources in lead container encapsulated in concrete-filled A/N can; 2 kg thorium oxide; 2,390 kg DU; 75 Ci tritium.

PIT 17

"Casseto" and "Triga" parts from NTS; one each 0.5 mCi Ra-226/Be source, one each 36 Ci Co-60 source, and one each 6.0 Ci Sr-90 source each in a lead container encapsulated in concrete-filled 55-gallon drum; 11 each Kr-85 cells (8.1 mCi total); 2 each uranium carbide nose cones; uranium and zirconium scrap in a 55-gallon drum; 30 Ci tritium lab waste in brass tube; neutron generator tubes; dummy DU reservoir; DU scrap and machine parts; test specimens; brazed to aluminum; fusing and firing assemblies; DU-contaminated weapon components; 3 kg thorium oxide; 457 kg DU.

PIT 18

Pu-238 contaminated paper, gloves, small equipment, components, wire, and sockets; 12 each spark gap tubes; 7 each 10 microCi Ra-226/Be sources in a lead container encapsulated in concrete-filled 55-gallon drum; Pu-238 contaminated vacuum pump; radioactive rock; electrical

cables from junction box; reactor fuel element ends (5 rem/hr on contact); neutron generator tubes; Pershing missile test debris; DU-contaminated weapons components; 155 mm gun projectile with a Sb-124 source; 762 kg DU; 45 Ci tritium.

PIT 19

Tritium-contaminated buckets, clothing, swipes, rags, paper, work gloves, vacuum cleaner, and decontamination materials; reactor fuel element ends (5 rem/hr on contact); one each Sb-124 source projectile (10 rem/hr on contact); neutron generator tubes; scrap metal, DU-contaminated muffle furnace; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; one each 3.5 microCi Co-60 source and one each 4.1 microCi Co-60 source in a lead container encapsulated in concrete-filled 55-gallon drum; Pershing missile test debris; tritium bed; scrap iron; Pu-238/239 contaminated filters; 621 kg DU; 60 Ci tritium.

PIT 21

Two each 3.4 microCi Co-60 sources, one each 31.8 microCi Sr-90 source, one each 100 microCi Co-60 source, one each leaking Sb-124 source, and one each spent Cs-137 source in a lead container encapsulated in concrete-filled 55-gallon drum; NTS irradiated material; DU-contaminated paper, towels, and poly bottles; plutonium oxide-contaminated filters, towels, tape, paper, cleaning and decontamination materials; 4 each irradiated thermal batteries; oil diffusion pump and baffle; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; neutron generator tubes; Pershing missile test debris; DU-contaminated weapons components; 16 kg thorium; 1,731 kg DU; 0.1 grams Pu-238; 30 Ci tritium.

PIT 24

“Hudson Moon” and “Mint Leaf” test debris from NTS; 3 each 500 microCi Ra-226 ionization alphatron gauges encapsulated in a concrete-filled A/N can; one each 45 Ci Co-60 source in a lead shield housing; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; reactor fuel element ends (5 rem/hr on contact); tritium-contaminated General Electric vacuum system, trigger gauge, transducers, hoods, vacuum pump, and panels; Pu-238, Pu-239, U-235, and U-238 contaminated glove box, gamma probe, and stereo microscope; neutron generator tubes; Pershing missile test debris; DU-contaminated weapons debris; 140 kg DU; 60 Ci tritium.

PIT 25

Stainless steel sample cylinders; tritium-contaminated flexible vent; Pu-239 contaminated microscope slide and slide clamps; “Hudson Moon” test debris from NTS; irradiated diodes,

transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; one each 3.5 Ci Ir-192 source encapsulated in concrete-filled 5-gallon A/N can; Ta-182 wire, needles, and foil in lead pigs; 4 each 10 microCi Ra-226/Be sources in a lead container encapsulated in concrete-filled 55-gallon drum; one each 30 Ci Ir-192 source encapsulated in concrete-filled 10-gallon A/N can; Ba-133 reactor bolts; DU ballast, machine chips, cuttings, and turnings; head filters and prefilters; DU-contaminated penetration vehicles; one each Pu-238 contaminated stereo microscope, glove box, balance, and manipulator arm; reactor fuel element ends (5 rem/hr on contact); DU-contaminated ceramic base plates and electric furnace; irradiated scrap nickel and reactor material; DU-contaminated sputtering shield, O-rings, and steel wool; 15 each irradiated fission chambers; Be-contaminated glove box and balance; irradiated floor and exhaust hood coverings; tritium-contaminated ion pump; MFP-contaminated transistors, diodes, resistors, circuits, paper, and plastic; one each iridium iriditron, one each 11.6 microCi Ra-226 dew pointer in brass cylinder, one each DU aft simulator; neutron generator tubes; SRAM missile test debris; DU-contaminated weapons components; 1,431 kg DU; 76.5 Ci tritium.

PIT 26

Co-57 contaminated cleanup debris; DU machine chips, turnings, and cuttings; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; 5 each carbon rings; DU-contaminated cloth, towels, and paper; MFP-contaminated machining wastes; 4 each 4.0 Ci Co-60 sources in a lead container encapsulated in concrete-filled 55-gallon drum; 100 microCi Na-22; DU-contaminated Pershing missile debris; DU-contaminated Sierra Army Depot debris; 18 each 1.8 microCi Ra-226 ionization alphatron gauges encapsulated in concrete-filled 32-gallon A/N can; Ta-182 wires in a lead pig; 3 each Victoreen Sr-90 ion chambers; DU-contaminated penetration ballast, noses, and aft simulators; 5 each sealed 389 microCi Ba-133 sources; 5 each sealed 160 microCi Ra-226 sources; 2 each sealed 10 microCi Ra-226 check sources; 2 each sealed 2.2 microCi Cs-137 check sources; 3 each sealed 4.6 microCi Co-60 solution in glass ampules; one each sealed 1.0 microCi Sr-90 solution in a glass ampule; and one each sealed 0.6 microCi Kr-85 gas in a glass ampule; firing and fusing sets; DU-contaminated weapons components; 5,525 kg DU; 88.5 Ci tritium.

PIT 27

One each DU nose ballast; one each tritium-contaminated shipping container; DU plates; 3 each empty steel gas cylinders; tritium targets; 2 each DU penetrators; enriched uranium tensile bars alloyed with Fe-50; 1 kg thorium oxide; neutron generator tubes; 155 mm gun debris; 3,246 kg DU; 81 Ci tritium.

PIT 28

6 each 55-gallon drums containing DU debris; Cs-137 contaminated debris in sealed A/N can; one each 100 microCi Victoreen Sr-90 ion chamber; 10 each irradiated headers; DU-contaminated tapered cantilever and double cantilever; neutron generator tubes.

PIT 30

20 each 0.4 Ci neutron activated aluminum reflector plates encapsulated in concrete; 4 each 187 Ci Co-60 neutron activated stainless steel tubes encapsulated in concrete; activated stainless steel pipe containing reactor instrumentation (1,000 rem/hr on contact); thoria capsules and fragments.

PIT 31

Cs-137 contaminated reactor waste in sealed A/N can; 8 each DU ballast plugs; DU machine chips, turnings, and cuttings; 19 each highly oxidized DU plates; miscellaneous operational and cleanup wastes including towels, paper, packing material, wire, gloves, and tape; one each 10 microCi Ra-226 ionostat; one each 45 mCi Kr-85 ion generator; prefilters from exhaust systems; one each 4 mCi Ra-226/Be source, 4 each DU plates; 3 each uranium/zirconium samples; one each 16 mCi Se-75 source in steel block; 2 each 55-gallon drums contaminated with DU oxide; quartz cloth contaminated with thorium; 1-gallon toluene absorbed on vermiculite in sealed A/N can; neutron generator tubes and targets; DU-contaminated weapons test debris; Pershing missile test debris; 2,460 kg DU; 27.7 Ci tritium.

PIT 32

Two pints deuterium water absorbed on vermiculite in sealed 2-gallon A/N can; one each 150 mCi Ta-182 source in lead pig; 2 each Ta-182 plugs removed from a rain erosion rocket in sealed A/N can; neutron generator tubes and targets; DU-contaminated inner shield assembly; Ra-226, Na-22, Ba-133, Co-60, Co-57, Mo-54, mixed isotopes (1.0 mCi) in lead pig; 6 each 1.0 mCi Se-75 sources in lead pig; 6 kg DU-contaminated lithium tetra-borate; 10 each Po-210 static eliminators; 25 each obsolete 240 mCi Po-210 static eliminators; one each 300 mCi Ba-226 source in sealed A/N can; one each 1.0 microCi Sm-151 source in sealed A/N can; one each 0.1 mCi Pm-147 source in a sealed A/N can; tritium-contaminated glove box; 549 kg DU; 55.6 Ci tritium.

Trace Gd-153, Eu-152, Ce-144, Sr-85, Ba-133, Ag-110m, Tc-199, Ni-63, Na-22, and Pm-147.

PIT 33

One each 24 kg DU sphere; one each 86 Ci Co-60 source in 4,000 lb. lead cask; 15 each 70 mCi Co-60 sources, one each 1.0 mCi Pm-147 source, one each 350 mCi Se-75 source, 15 each 85

mCi Cs-137 sources, and 10 each 25 mCi Ra-226 sources encapsulated in concrete-filled 55-gallon drums; thorium-contaminated quartz cloth; 200 grams uranium hydride; one each 50 Ci Kr-85 source encapsulated in a concrete-filled A/N can; activated stainless steel roller plate; TA-5 hot cell decontamination debris; one each irradiated balance; fuel element cladding and associated parts from reactor instrumented fuel elements, vacuum system, filters, and tools (2 rem/hr on contact); irradiated, disassembled pressure vessel and crucible; tritium targets and tubes; Three Mile Island radiation detector; 1.6 kg Be; 2,125 kg DU; 822 Ci tritium; 1kg thorium.

PIT 34

One each 110 Ci Co-60 radiography source encapsulated in concrete-filled A/N can; one each ultra-sonic thermometer consisting of a stainless steel tube loaded with copper, cobalt, tantalum, thoria, nickel, and iron (15 rem/hr on contact); activated stainless steel tubing (2 rem/hr on contact); obsolete experimental equipment and parts (3 rem/hr on contact); one each Cs-137 contaminated WESF capsule; neutron generator tubes and targets; 200 grams activated silver; firing sets; uranyl nitrate coatings of foil; trough assembly used in fuel element cleanup; 1,676 kg DU; 328 Ci tritium.

PIT 35

Neutron generator tubes and targets; neutron activated brass; 4 each 55-gallon drums DU from White Sands Missile Range; one each activated stainless steel containment canister; 686 kg DU; 203 Ci tritium.

PIT 36

Neutron generator tubes and targets; one each microcomputer; irradiated diodes, transistors, capacitors, resistors, circuit boards, voltage regulators, and other miscellaneous electrical components; 3 each activated stainless steel containment canisters wrapped in polyethylene sheeting; one each weapon shipping and handling container; thorium-contaminated Polaris missile sections; rings from reactor fuel elements (1.7 rem/hr on contact); 4 each 55-gallon drums containing wastes contaminated with fission products; 673 kg DU; 13.1 kg lithium.

PIT 37

Empty, no contents.

PIT U-1

1,589 kg DU in chips, machine turnings, shavings, cuttings, residue, and scrap.

PIT U-2

5,119 kg DU in chips, machine turnings, shavings, cuttings, residue, and scrap; one each irradiated melt chamber; one each copper crucible containing DU scrap.

PIT U-3

1,114 kg DU in chips, machine turnings, shavings, cuttings, residue, and scrap; 1,000 lbs. of Burn Site DU-contaminated soil and debris; one each DU-contaminated 300 lb. crucible.

Inventory of Inhalation Toxicology Research Institute – Lovelace Biomedical and Environmental Research, Inc. Disposed in Trench E [page 1]

INHALATION TOXICOLOGY RESEARCH INSTITUTE

LOVELACE BIOMEDICAL AND ENVIRONMENTAL RESEARCH INSTITUTE, INC.

RADIOACTIVE SHIPMENT RECORD FORM

From

Date 4/28/80

Page 1 of 4

Item No.	Rad. Level (mr/hr) Surface	Rad. Level (mr/hr) at 3 feet	External Contamination Survey (CPM)	Isotope(s)	Container Type	Radioactive Millicuries	Physical State	Contents	Container Cubic Feet
1	BKG.	BKG.	<100	^{238}Pu ^{239}Pu	55 Gal. Drum	.5	Solid	Plastic, glass, Paper	7.5
2	"	"	"	^{238}Pu ^{144}Pu	"	"	"	"	"
3	"	"	"	^{238}Pu ^{239}Ce	"	"	"	"	"
4	"	"	"	^{238}Pu	"	"	"	"	"
5	"	"	"	^{238}Pu	"	"	"	"	"
6	"	"	"	^{238}Pu	"	"	"	"	"
7	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
8	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
9	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
11	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
12	"	"	"	^{238}Pu ^{241}Am	"	"	"	"	"
13	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
14	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
15	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
16	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	"
17	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	"
18	50	5	"	^{144}Ce	"	100	"	"	"
19	BKG.	BKG.	"	^{144}Ce ^{238}Pu	"	.5	"	"	"
25	"	"	"	^{134}Cs ^{239}Pu	"	"	"	"	"
26	"	"	"	^{134}Cs ^{239}Pu	"	"	"	"	"
27	"	"	"	^{134}Cs ^{241}Am	"	"	"	"	"
28	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
29	"	"	"	^{134}Cs ^{239}Pu	"	"	"	"	"
30	"	"	"	^{134}Cs ^{241}Am	"	"	"	"	"
31	"	"	"	^{134}Cs ^{239}Pu	"	"	"	"	"
32	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
33	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
34	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
35	"	"	"	^{239}Pu ^{241}Am	"	"	"	"	"
36	10.	0.4	"	^{238}Pu ^{169}Yb	"	50 (Yb^{169})	"	"	"
37	BKG.	BKG.	"	^{144}Ce ^{238}Pu	"	.5	"	"	"
38	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
39	"	"	"	^{134}Cs ^{239}Pu	"	"	"	"	"
40	"	"	"	^{238}Pu ^{241}Am	"	"	"	"	"
				TOTALS		166			255

All of the waste described above contains no free liquids and no transuranic elements with a radioactivity concentration greater than 10 nanocuries per gram.

G. J. Nowysz 4/30/80

Generator's Signature Date

Carrier's Signature Date

Inventory of Inhalation Toxicology Research Institute – Lovelace Biomedical and Environmental Research, Inc. Disposed in Trench E [page 2]

INHALATION TOXICOLOGY RESEARCH INSTITUTE

LOVELACE BIOMEDICAL AND ENVIRONMENTAL RESEARCH INSTITUTE, INC.

RADIOACTIVE SHIPMENT RECORD FORM

From _____

Date 4/28/80

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Item No.	Rad. Level (mr/hr) Surface	Rad. Level (mr/hr) at 3 feet	External Contamination Survey (CPM)	Isotope(s)	Container Type	Radioactive Millicuries	Physical State	Contents	Container Cubic Feet
41	BKG.	BKG.	~~<100~~	^{144}Ce ^{239}Pu	55 Gal.drum	.5	Solid	Glass,paper,plastic	7.5
42	"	"	"	^{147}Pm ^{238}Pu	"	"	"	"	"
44	22	2	"	^{134}Cs ^{144}Ce	"	50	"	"	"
45	190	10	"	^{144}Ce ^{137}Cs	"	500	"	"	"
46	BKG.	BKG.	"	^{144}Ce ^{238}Pu	"	.5	"	"	"
47	15	1	"	^{147}Pm	"	15,000	"	"	"
48	BKG.	BKG.	"	^{144}Ce ^{239}Pu	"	.5	"	"	"
49	"	"	"	^{144}Ce ^{241}Am	"	"	"	"	"
50	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
51	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
54	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
55	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
56	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
57	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
58	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
59	5	.5	"	^{144}Ce ^{238}Pu	"	10(^{144}Ce)	"	"	"
60	BKG.	BKG.	"	^{238}Pu ^{239}Pu	"	.5	"	"	"
61	"	"	"	^{239}Pu ^{241}Am	"	"	"	"	"
62	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
63	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
64	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
65	"	"	"	^{169}Yb ^{238}Pu	"	"	"	"	"
66	"	"	"	^{239}Pu ^{241}Am	"	"	"	"	"
67	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
68	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
69	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
70	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
71	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
72	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
73	50	6	"	^{134}Cs ^{144}Ce	"	50	"	"	"
74	60	7	"	^{134}Cs ^{144}Ce	"	50	"	"	"
75	40	5	"	^{134}Cs ^{144}Ce	"	50	"	"	"
76	BKG.	BKG.	"	^{144}Ce	"	.5	"	"	"
77	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	" RI
						15724			255

TOTALS

All of the waste described above contains no free liquids and no transuranic elements with a radioactivity concentration greater than 10 nanocuries per gram.

J. J. Thomas 4/30/80

Consignor's Signature Date

Carrier's Signature Date

Inventory of Inhalation Toxicology Research Institute – Lovelace Biomedical and Environmental Research, Inc. Disposed in Trench E [page 3]

INHALATION TOXICOLOGY RESEARCH INSTITUTE

LOVELACE BIOMEDICAL AND ENVIRONMENTAL RESEARCH INSTITUTE, INC.

RADIOACTIVE SHIPMENT RECORD FORM

From _____

Date 4/28/80

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Item No.	Rad. Level (mr/hr) Surface	Rad. Level (mr/hr) at 3 feet	External Contamination Survey (CPM)	Isotope(s)	Container Type	Radioactive Millicuries	Physical State	Contents	Container Cubic Feet
78	BKG.	BKG.	< 100	^{144}Ce ^{238}Pu	55Gal.drum	.5	Solid	Glass,paper,plastic	7.5
79	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	"
81	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
82	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
83	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
84	"	"	"	^{239}Pu ^{241}Am	"	"	"	"	"
85	"	"	"	^{137}Cs ^{239}Pu	"	"	"	"	"
86	20	.5	"	^{144}Ce ^{238}Pu	"	50(^{144}Ce)	"	"	"
87	BKG.	BKG.	"	^{169}Yb ^{238}Pu	"	.5	"	"	"
88	"	"	"	^{134}Cs ^{238}Pu	"	"	"	"	"
91	"	"	"	^{134}Cs ^{238}Pu	"	"	"	"	"
92	"	"	"	^{134}Cs ^{238}Pu	"	"	"	"	"
93	"	"	"	^{134}Cs ^{238}Pu	"	"	"	"	"
94	40	5	"	^{106}Ru	"	20	"	"	"
95	110	7	"	^{106}Ru	"	60	"	"	"
96	BKG.	BKG.	"	^{238}Pu ^{239}Pu	"	.5	"	"	"
97	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
98	"	"	"	^{238}Pu ^{241}Am	"	"	"	"	"
99	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
100	"	"	"	^{14}C ^{134}Cs	"	"	"	"	"
101	"	"	"	^{239}Pu ^{241}Am	"	"	"	"	"
102	25	1	"	^{169}Yb ^{238}Pu	"	50 (^{169}Yb)	"	"	"
103	BKG.	BKG.	"	^{169}Yb ^{238}Pu	"	.5	"	"	"
104	"	"	"	^{169}Yb ^{238}Pu	"	"	"	"	"
107	3	0	"	^{169}Yb ^{238}Pu	"	10 (^{169}Yb)	"	"	"
108	BKG.	BKG.	"	^{144}Ce ^{238}Pu	"	.5	"	"	"
109	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	"
110	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
111	"	"	"	^{106}Ru ^{238}Pu	"	"	"	"	"
112	"	"	"	^{106}Ru ^{238}Pu	"	"	"	"	"
113	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
114	7	1	"	^{134}Cs ^{238}Pu	"	10 (^{134}Cs)	"	"	"
115	BKG.	BKG.	"	^{238}Pu ^{239}Pu	"	.5	"	"	"
117	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
TOTALS						214			255

All of the waste described above contains no free liquids and no transuranic elements with a radioactivity concentration greater than 10 nanocuries per gram.

J. J. Thompson 4/30/80

Customer Signature Date

Carrier's Signature Date

Inventory of Inhalation Toxicology Research Institute – Lovelace Biomedical and Environmental Research, Inc. Disposed in Trench E [page 4]

INHALATION TOXICOLOGY RESEARCH INSTITUTE

LOVELACE BIOMEDICAL AND ENVIRONMENTAL RESEARCH INSTITUTE, INC.

RADIOACTIVE SHIPMENT RECORD FORM

From

Date 4/28/80

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Item No.	Rad. Level (mr/hr) Surface	Rad. Level (mr/hr) at 3 feet	External Contamination Survey (CPM)	Isotope(s)	Container Type	Radioactive Millicuries	Physical State	Contents	Container Cubic Feet
118	BKG.	BKG.	< 100	^{106}Ru ^{238}Pu	55 Gal. drum	.5	Solid	Glass, plastic, paper	7.5
119	"	"	"	^{106}Ru ^{238}Pu	"	"	"	"	"
120	"	"	"	^{90}Sr ^{144}Ce	"	"	"	"	"
121	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	" R
122	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
123	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
124	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
125	"	"	"	^{169}Yb ^{238}Pu	"	"	"	"	"
128	"	"	"	^{169}Yb ^{238}Pu	"	"	"	"	"
131	"	"	"	^{239}Pu ^{241}Am	"	"	"	"	"
132	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
134	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
135	"	"	"	^{238}Pu ^{239}Pu	"	"	"	"	"
136	"	"	"	^{238}Pu ^{241}Am	"	"	"	"	"
137	"	"	"	^{238}Pu ^{241}Am	"	"	"	"	"
242	"	"	"	^{238}Pu ^{241}Am	"	"	"	"	"
11 247	"	"	"	^{144}Ce ^{239}Pu	"	"	"	"	"
D	BKG.	BKG.	<100	^{137}Cs ^{238}Pu	Plywood Box	.5	Solid	Glass, paper, plastic,	121
G	"	"	"	^{134}Cs ^{144}Ce	"	"	"	metal	91
B	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	154
H	"	"	"	^{90}Sr ^{137}Cs	"	"	"	Manipulator cell	411
J	"	"	"	^{137}Cs ^{144}Ce	"	"	"	Metal, paper, glass,	121
K	"	"	"	^{137}Cs ^{144}Ce	"	"	"	" plastic	91
M	"	"	"	^{137}Cs ^{144}Ce	"	"	"	"	91
L	"	"	"	^{137}Cs ^{144}Ce	"	"	"	"	121
F	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	91
N	"	"	"	^{137}Cs ^{144}Ce	"	"	"	"	121
A	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	121
E	"	"	"	^{144}Ce ^{238}Pu	"	"	"	"	91
I	"	"	"	^{169}Yb ^{238}Pu	"	5.0	"	Glove Box, paper, glass and plastic	441
TOTALS						19.5			2193.5

All of the waste described above contains no free liquids and no transuranic elements with a radioactivity concentration greater than 10 nanocuries per gram.

J. J. Thompson 4/30/80

Customer Signature Date

Carrier's Signature Date

[Picture] Cs-137 contaminated shipping cask and semi-tractor trailer. Only the semi-tractor trailer was buried in Trench F.

APPENDIX C

Notices of the Public Meetings on the Sandia National Laboratories Mixed Waste Landfill Peer Review

Advertisements of meetings published in the Albuquerque Journal and Albuquerque Tribune

Notice of Public Meeting To Discuss Sandia Laboratory's Mixed-Waste Landfill

WERC: A Consortium for Environmental Education and Technology Development will host the first in a series of public meetings regarding the Mixed-Waste Landfill located on Sandia National Laboratory's property in Albuquerque, NM. The objective of the meeting will be to discuss the process under which an independent peer review will be conducted to examine existing technical data, QA/QC for data collection, appropriateness of data, and the respective relevant technical conclusions made. The public is invited to attend these meetings.

Dates: March 6 and 7
Time: 6:30-8 p.m.
Location: UNM Division of Continuing Education and Community
Services Building, Room C
1634 University Blvd., NE

For more information, call (800) 523-5996.

Notice of Public Meeting To Discuss Sandia Laboratory's Mixed-Waste Landfill

WERC: A Consortium for Environmental Education and Technology Development will host the second in a series of public meetings regarding the Mixed-Waste Landfill located on Sandia National Laboratory's property in Albuquerque, NM. Presentations will be made by organizations that have previously been involved in reviewing the data. The public is invited to attend these meetings.

Dates/Time: March 22; 10 a.m. to noon, continuing at 2 p.m. to 5 p.m.
March 23; 9 a.m. to noon, continuing at 1 p.m. to 5 p.m.

Location: Albuquerque Doubletree Inn
Cutter Room, lower lobby level
201 Marquette Ave., NW

For more information, call (800) 523-5996.

Notice of Meeting To Discuss Sandia Laboratories' Mixed-Waste Landfill

WERC: A Consortium for Environmental Education and Technology Development will host the third in a series of meetings regarding the Mixed-Waste Landfill located on Sandia National Laboratories' property in Albuquerque, NM. The purpose of this panel meeting is to review the preliminary conclusions of panel members relative to adequacy of the scientific study of the landfill performance. The public is invited to attend this meeting.

Dates/Time: May 11, 8:30 a.m.

Location: Albuquerque Doubletree Inn
Cutter Room, lower lobby level
201 Marquette Ave., NW

For more information, call (800) 523-5996.

Sandia Laboratories' Mixed-Waste Landfill Response to Public Comment on Draft Report

WERC: A Consortium for Environmental Education and Technology Development will host an open public meeting regarding the Mixed-Waste Landfill located on Sandia National Laboratory's property in Albuquerque, NM. The objective of the meeting will be to respond to written public comments on a draft report on WERCs independent peer review. The draft report was opened for public review on July 10. The public has been invited to comment on the draft report in writing for a 30-day period ending August 9. The draft report can be accessed on www.werc.net or by calling WERC at the number listed below.

Date: August 16
Time: 6:30-8:30 p.m.
Location: UNM Division of Continuing Education and Community
Services Building, Room C
1634 University Blvd., NE

For more information, call (800) 523-5996.

APPENDIX D

Documents Available to

Peer Panel and Public

Appendix D
Documents Available to Peer Panel and Public

WERC DOCUMENT #	DOCUMENT NAME
1	Strategy for Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico (April 1999)
2	Mixed Waste Landfill Map and Inventory, Volume 1
3	Mixed Waste Landfill Map and Inventory, Volume 2
4	Mixed Waste Landfill Map and Inventory, Volume 3
5	Report of the Phase 1 RCRA Facility Investigation of the Mixed Waste Landfill (September 1990)
6	Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico (September 1996)
7	DOE Oversight Bureau's Comments on Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico (September 1996)
8	Environmental Restoration Project DOE/SNL/NM Response to NMED October 30, 1998, NOD for "Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico" (January 1999)
9	Geologic Study of Near-Surface Sediments, Volumes I (September 1998)
10	Geologic Study of Near-Surface Sediments, Volume II (September 1998)

11	Addendum to Geologic Study of Near Surface Sediments (December 1998)
12	Solute Interactions and Transport in Soils from Waste Disposal Sites at Sandia National Laboratories (June 1982)
13	Analysis of Instantaneous Profile Test Data from Soils near Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories, New Mexico (February 1996)
14	Results of the 1992 Sandia National Laboratories Hazardous Air Pollutant Baseline Study (November 1992)
15	Measurement of Tritium and VOC Fluxes from the Mixed Waste Landfill at Sandia National Laboratories, New Mexico (January 1994)
16	Tritium in Surface Soils at the Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories, New Mexico (March 1996)
17	Mixed Waste Landfill Semiannual Groundwater Monitoring Report, April 1999, Sandia National Laboratories/New Mexico (August 1999)
18	Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 1
19	Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 2
20	Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 3
21	Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 4

22 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 5

23 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 6

24 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 7

25 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 8

26 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 9

27 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 10

28 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 11

29 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 12

30 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 13

31 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 14

32 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 14-a

33 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 14-b

34 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 14-c

35 Semiannual Groundwater Sampling at the Mixed Waste Landfill, Sandia National Laboratories/New Mexico, Volume 14-c2

36 Mixed Waste Landfill Review by Mark Baskaran-Final Report dated July 5, 2000

37 City of Albuquerque-Mixed Waste Landfill Data Analysis by Douglas Earp dated November 29, 2000

38 Draft Report on Background Groundwater Sampling at the Mixed Waste Landfill Sandia National Laboratories, Albuquerque - September 1990 - Prepared by International Technology (IT) Corporation (April 1991)

39 Draft Report - Comprehensive Environmental Assessment and Response Program - Phase I: Installation Assessment - Sandia National Laboratories - Prepared by the Department of Energy, Albuquerque Operations Office - Environment, Safety and Health Division - Environmental Programs Branch (September 30, 1987)

40 Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico - Prepared by Environmental Restoration Project, Sandia National Laboratories (September 23, 1999)

41 Report on Quarterly Ground-Water Sampling at the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, July 1991 - Prepared by IT Corporation (May 1992)

42 Groundwater Monitoring Wells Installation Mixed Waste Landfill - Prepared by Ecology and Environment, Inc. (December 1989)

43 Draft Final RCRA Facility Assessment Report of Solid Waste Management Units at Sandia National Laboratories, Albuquerque - Prepared by A.T. Kearney Inc., and Harding Lawson Associates (April 1987)

44 Groundwater Monitoring Program - Mixed Waste Landfill Ground Water Sampling and Analysis Plan (September 1990)

45 Strategy for Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories (April 12, 1999)

46 Report on Quarterly Ground-water Sampling at the Mixed Waste Landfill Sandia National Laboratories, Albuquerque, April 1991 - Prepared by IT Corporation (October 1991)

47 Application of Non-Intrusive Geophysical Techniques at the Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories, New Mexico - Printed March 1996

48 Unsaturated Hydrologic Flow Parameters Based on Laboratory and Field Data for Soils Near the Mixed Waste Landfill, Technical Area III, Sandia National Laboratories/New Mexico - Printed August 1996

49 Report on Semiannual Groundwater Sampling at the Mixed Waste Landfill Sandia National Laboratories/New Mexico, March Through May 1994, Volume 1 - Prepared by IT Corporation (February 1995)

50	Preliminary Data From an Instantaneous Profile Test Conducted Near the Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories/New Mexico - Printed April 1996
51	Analysis of Instantaneous Profile Test Data from Soils Near the Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories/New Mexico - Printed February 1996
52	Report on Semiannual Ground-water Sampling at the Mixed Waste Landfill Sandia National Laboratories/New Mexico, January 1993 - Prepared by IT Corporation (July 1993)
53	A Preliminary Human Health Risk Assessment for the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico - Prepared by Argonne National Laboratory (January 1995)
54	Report on Semiannual Ground-water Sampling at the Mixed Waste Landfill Sandia National Laboratories/New Mexico - November 1993 - Prepared by IT Corporation (May 1994)
55	Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill Sandia National Laboratories, New Mexico (September 23, 1999)
56	Compliance Activities Work Plan for the Mixed Waste Landfill (August 26, 1991)
57	Mixed Waste Landfill Phase 2 RCRA Facility Investigation Work Plan
58	Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation Dated September 1996, Volume 1 (June 15, 1998)
58a	Attachment to #58 - Nickel Concentrations in Groundwater at the Mixed Waste Landfill

59 Draft Report on Quarterly Ground-water Sampling at the Mixed Waste Landfill, October 1991 - Prepared by IT Corporation (May 1992)

60 Fiscal Year 1998 Annual Groundwater Monitoring Report (March 1999)

61 Report on Quarterly Ground-water Sampling at the Mixed Waste Landfill Sandia National Laboratories, Albuquerque, January 1991 - Prepared by IT Corporation (July 1991)

62 Draft Report on Semiannual Ground-water Sampling at the Mixed Waste Landfill Sandia National Laboratories, New Mexico July 1992 - Prepared by IT Corporation (January 1993)

63 Mixed Waste Landfill Project Location Maps

64 Mixed Waste Landfill Semiannual Groundwater Monitoring Report April, 1999 Sandia National Laboratories/New Mexico - Prepared by IT Corporation (August 1999)

65 Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico - Submitted to the New Mexico Environment Department September 23, 1999

66 Mixed Waste Landfill Design Report

67 Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico - Attachment #A - Preliminary Unsaturated Flow Modeling of the Design of a Closure Cover for the Mixed Waste Landfill dated September 23, 1999

68 Responses to the New Mexico Environment Department Request for Supplemental Information issued June 5, 2000

69 Request for Supplemental Information - Deployment of an Alternative Cover and Final Closure of the Mixed Waste

Landfill, September 23, 1999 - Requested by the New Mexico Environment Department, February 16, 2001

70 FY97-99 Vegetation Analysis of ALCD Soil Amended Landfill Cover Plots

71 Construction Overview of Six Landfill Cover Designs

72 Alternative Landfill Cover Demonstration FY2000 Annual Data Report

73 Synopsis of Sandia/DOE Technical Concerns Regarding the Mixed Waste Landfill Report Prepared by Dr. Mark Baskaran, Department of Geology, Wayne State University

74 The Department of Energy and Sandia National Laboratories Response to Dr. Mark Baskaran's Final Report, "Mixed Waste Landfill Review"

75 Sigma Five Consulting Comments on July 12, 2000 Presentation of Dr. Baskaran by Fritz A. Seiler, dated August 5, 2000

76 Dr. Baskaran's Response to Seiler's Comments on the Mixed Waste Landfill, dated August 11, 2000

77 Comments on the Reply to My Review of the Baskaran Evaluation of the Sandia Mixed Waste Landfill Work by Fritz A. Seiler

78 Report on Semiannual Ground-Water Sampling at the Mixed Waste Landfill Sandia National Laboratories/Albuquerque January 1992 - Prepared by IT Corporation May 1992

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89 New Mexico Environment Department Oversight Bureau - Mixed Waste Landfill Sampling Data Summary provided for WERC Peer Review Panel 3/22-3/23/01

90 Ground Water Sampling Results - Sandia National Laboratories/Albuquerque for Area MW-1

91	Results of Ground Water Sampling at Sandia National Laboratories/Albuquerque Mixed Waste Landfill for Area MW-2
92	Results of Ground Water Sampling at Sandia National Laboratories/Albuquerque for Area MW-3
93	Ground-Water Sampling at the Mixed Waste Landfill - Area MW-4
94	A(n) Water, Non-Filtered Sample Submitted to the State of New Mexico, Department of Health, Scientific Laboratory Division, January 19, 2001 for Area MW-5 and MW-6
95	Results of Ground Water Sampling at Sandia National Laboratories/Albuquerque Mixed Waste Landfill - Area BW-1
96	Results of Non-Aqueous Soil Samples Submitted to American Environmental Network Inc. on June 4, 1998
97	New Mexico Environment Department Hazardous and Radioactive Materials Bureau Approved Background Concentrations, Sandia National Laboratories/Kirkland Air Force Base - September 1997
98	Well Database Summary Sheet provided to WERC Peer Review Panel March 23, 2001
99	Mixed Waste Landfill (MWL) Data Analysis by Douglas Earp, City of Albuquerque, dated December 14, 2000
100	Mixed Waste Landfill Data Analysis by Douglas Earp, City of Albuquerque, dated November 29, 2000 submitted to Dr. Bruce Thomson, Chair, Groundwater Protection Advisory Board
101	Information on Surface Soil Sampling for Tritium and Soil Gas Surveys provided to WERC Peer Review Panel March 23, 2001

102	Cross Section across Mixed Waste Landfill provided to WERC Peer Review Panel March 23, 2001
103	Monitoring Wells in the Vicinity of the Mixed Waste Landfill provided to WERC Peer Review Panel March 23, 2001
104	Information on Environmental Settling provided to WERC Peer Review Panel March 23, 2001
105	Mixed Waste Landfill Map & Inventory, Attachment 2-1 provided to WERC Peer Review Panel March 23, 2001
106	Modeling the Infiltration of Reactor Coolant Water from Trench D at the Mixed Waste Landfill: Sandia National Laboratories/New Mexico by Ross Wolford, GRAM Inc., March 27, 1997
107	Documents on Mixed Waste Landfill Background and Facility Investigation provided to WERC Peer Review Panel on March 23, 2001
108	Presentation to WERC Peer Review Panel on March 22, 2001 by Sandia National Laboratories
109	Regulatory Review of the U.S. Department of Energy/Sandia National Laboratories Mixed Waste Landfill RCRA Facility Investigation prepared by William Moats, New Mexico Environment Department
110	Location and Surface Projection of Boreholes 1 through 15 - Tritium Sections
111	Paul Robinson Report: Summary of Data Identifying Organic Compounds in Ground Water Beneath the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico, January 2001 from William Moats, New Mexico Environment Department
112	Location and Surface Projection of Boreholes 1 through 15 - Cadmium

113	Comments by Douglas Earp regarding Sandia's December 14, 2000 Memo

APPENDIX E

Acronyms and Initialisms

Appendix E
Acronyms and Initialisms

Am	americium
A/N	Metal cans of various sizes for military ordinance storage
Ci	Curie(s)
Co	cobalt
COC	contaminate of concern
COPEC	constituents of potential ecological concern
Cs	cesium
DOE	U.S. Department of Energy
DU	depleted uranium
EPA	U.S. Environmental Protection Agency
ft.	feet or foot
g/cc	grams per cubic centimeter
H-3	tritium
HEPA	high efficiency particulate air (filter)
HI	hazard index
HQ	hazard quotient
K_H/	horizontal hydraulic conductivity
K_V	vertical hydraulic conductivity
mg/L	milligrams per liter
Mn	manganese
MWL	Mixed Waste Landfill
Na	sodium
Ni	nickel
NOAEL	no observed adverse effect level
Pb	lead
pCi/L	pico curies per liter
Pm	promethium
ppb	parts per billion
ppt	parts per trillion
Pu	plutonium
PVC	Polyvinyl chloride
Ra	radium
RESRAD	(residual radioactive) a computer model developed at Argonne National Laboratory for DOE to calculate site-specific radiation doses and cancer risk to chronically exposed on-site receptors
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
Ru	ruthenium
Sr	strontium
SWMU	Solid Waste Management Unit
Tc	technetium
TEDE	total effective dose equivalent
U	uranium
WERC	a Consortium for Environmental Education & Technology Development
Yb	ytterbium